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MAINTENANCE of EXTRUSION EQUIPMENT

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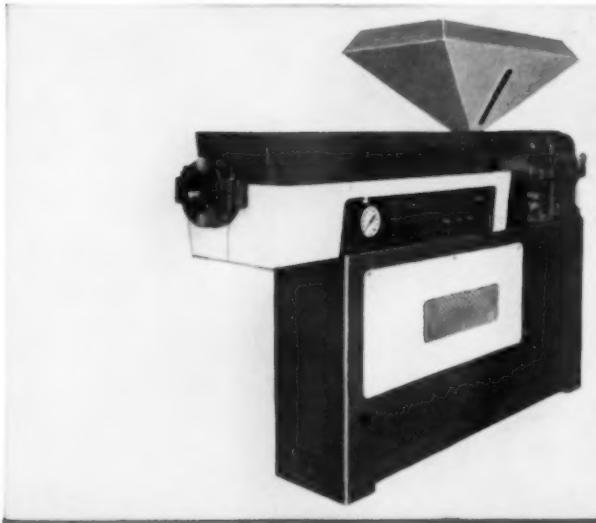
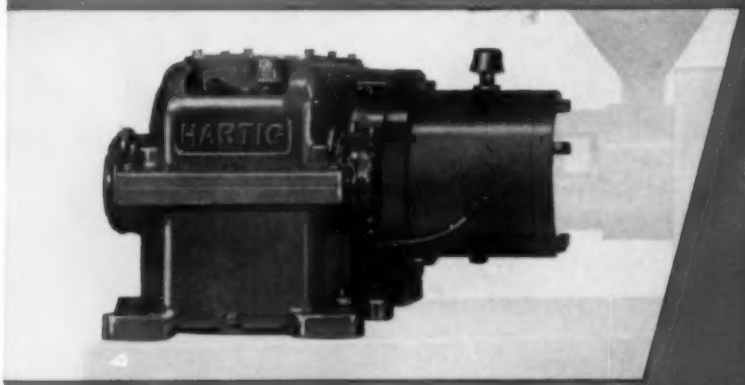
NEW HARTIG TRAPEZOIDAL* SERIES





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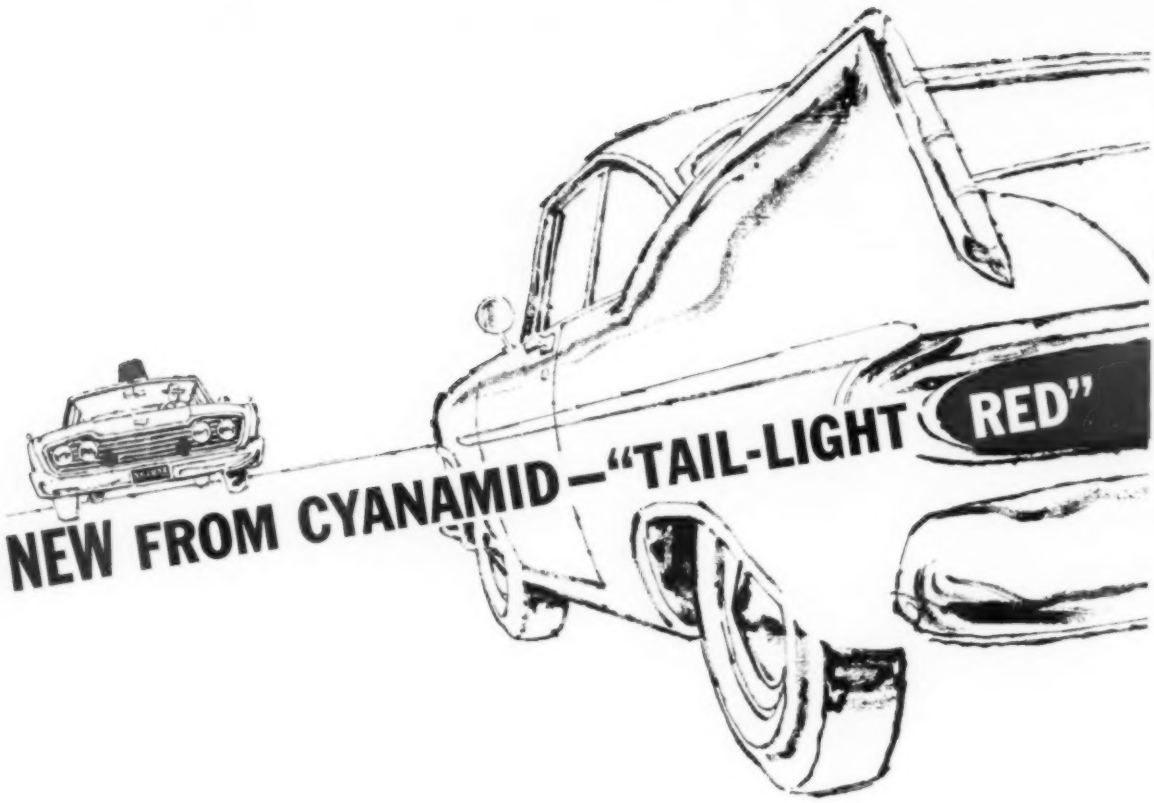

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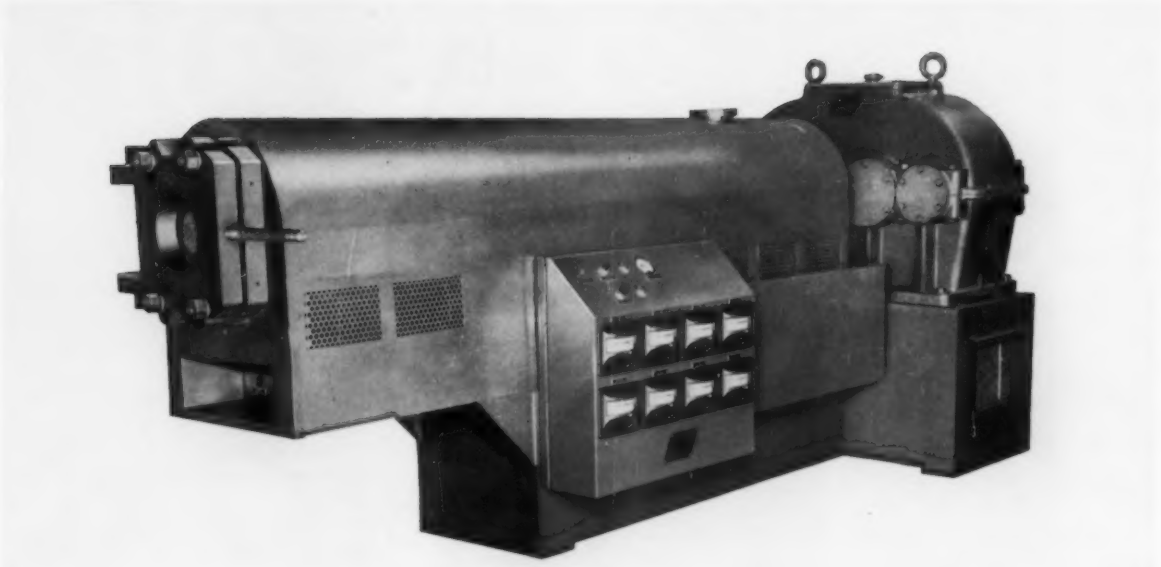

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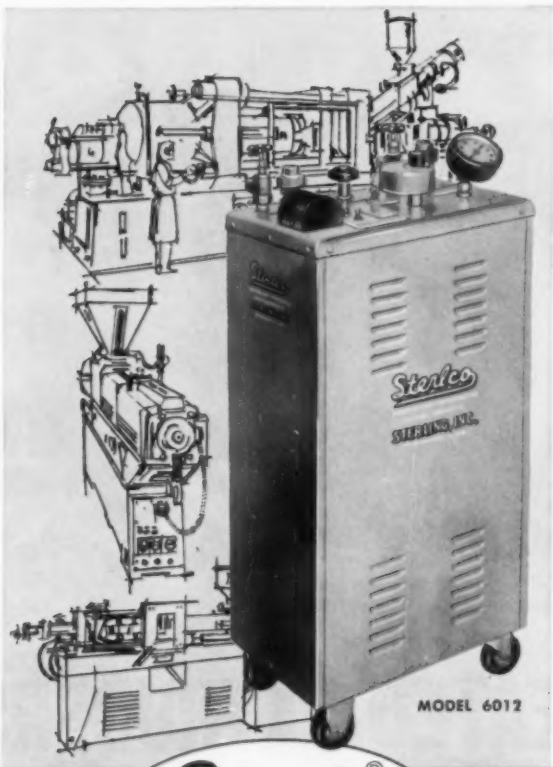

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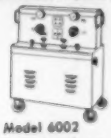
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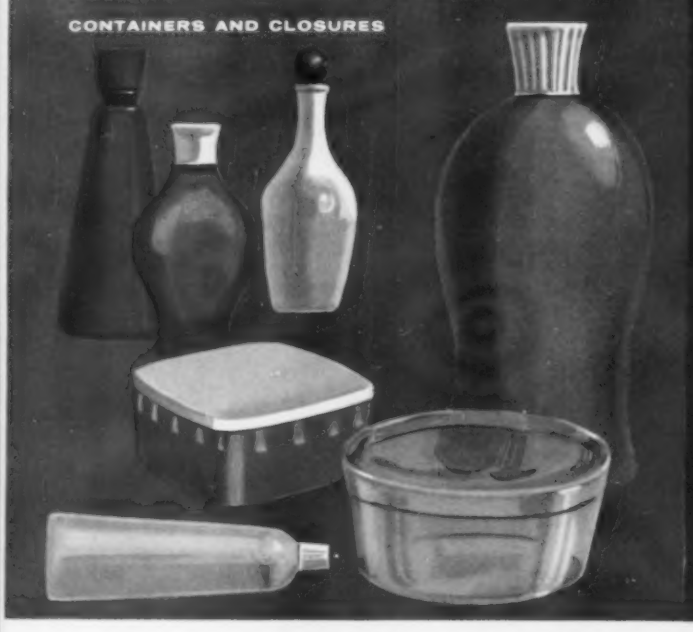
The Cover

Special "type treatment" is used to magnify certain highlights of this month's Table of Contents.



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FABRICS AND ROPE . . . marine rope bristles and industrial fabrics, automobil upholstery, awnings, furniture webbing an filters offer great promise as end products fo monofilaments made from AviSun Polypro pylene. It is lightweight (actually floats), i mildew proof, and has high tensile strengt as well as outstanding wearability and resist ance to chemicals and moisture.

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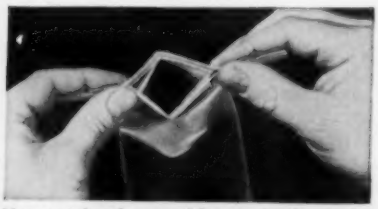
U.S.I. POLYETHYLENE NEWS

A series of advertisements for plastics and packaging executives by the makers of PETROTHENE® polyethylene resins

MAY 1960 U. S. Industrial Chemicals Co., Division of National Distillers and Chemical Corporation 99 Park Ave., N. Y. 16, N. Y.

Packaging Notes

A low-cost sterile polyethylene bag with a wire closure is now being used by the dairy industry for milk sampling and is reportedly finding application in a number of markets including frozen foods and cosmetics. In dairy use, the bags are said to reduce sampling costs up to 50% through replacement of bulky glass containers and elimination of washing, sterilizing and breakage.



New container is opened by pressing in on wire tape. A liquid-tight seal is formed by pulling tape taut, rolling top of bag and folding wire ends together.

The containers are made of clear, heavy polyethylene tubing, sealed at both top and bottom to keep the inside sterile. A line of perforations is provided for removing the sealed top. Below the perforations are two wires which make it possible to open or shut the bag without touching the sterile opening. The bag is resealed with the aid of the wires, which are bent to form a liquid-tight closure.

A newly introduced gusseting attachment for polyethylene bag-making machines now permits converting flat polyethylene tubing into gusseted tubing without the use of an air bubble.

The new unit permits printing and perforating of flat tubing before gusseting. Among the advantages claimed for this method of converting are improved printing quality, the possibility of printing on one half of the gussets of seamless bags, and placement of perforations within the gussets—without impairing the printed face of bags.

It is also reported that the unit eliminates telescoping rolls and overcomes any tendency of the film to block. Fewer roll changes are necessary, too, because flat tubing gives more footage than gusseted tubing on the same diameter roll. Attendant problems of winding up gusseted rolls are avoided.

The manufacturer reportedly offers complete gusseter kits for any model of polyethylene bag-making machine.

Gusseter attachment for bag-making machines permits converting flat polyethylene tubing into gusseted tubing without the use of an air bubble.

New U.S.I. Resin Produces Film With High Strength, Superior Appearance

Tailored for Produce Bags, New General Purpose Resin to Find Other Uses Where Combined Gloss, Clarity, and Strength Are Needed

The U.S.I. Polymer Service Laboratory has developed a new film-grade resin for producing polyethylene film with maximum clarity and gloss in combination with high impact strength. While the new resin—designated PETROTHENE 112—is tailored for the produce bag market, it should also find application in many other markets where combined gloss, clarity, and strength are desirable film properties.

Melt Index, gms/10 min.	3.0
Density, gms/cu. cm.	.921
Transmittance, %	65
Gloss, %	12
Haze, %	5
Dart Drop gm./F50	210
Draw Down, ft/min	330

Except for drawdown, properties of PETROTHENE 112 were determined on 1.5-mil blown tubing extruded at 330° F. stock temperature on 1½" MPM with 20/1 L/D ratio.

Special synthesis conditions during manufacture give the new resin outstanding flow properties which permit rapid extrusion of film. High drawdown rate of the resin makes it possible to extrude PETROTHENE 112 into thin gauge film without hot snap-offs. In preliminary tests, heat sealability of films made of the new resin was shown to be good under a wide variety of heat and pressure conditions. Treatment of the film for printability has also been accomplished with good results at commercial haul-off rates.

Recommended Extrusion Conditions

For peak gloss and clarity, PETROTHENE 112 should be extruded at about 330° F. stock temperature with a minimum blow ratio greater than 2 to 1.

PETROTHENE 112 is available in low-, medium- and high-slip formulations and in the no-slip form. A technical data sheet on this new resin may be obtained by writing to the Technical Literature Dept., U.S. Industrial Chemicals Co., or any of U.S.I.'s sales offices.

National Distillers' Annual Report is Polyethylene Coated

Cover stock for National Distillers and Chemical Corporation's recently issued 1959 Annual Report is extrusion coated with a protective layer of polyethylene. Advantages of using the polyethylene coating include durability, high gloss finish, and protection of the cover against tearing and soiling. The polyethylene coating also adds to the attractive appearance of the report.

National Distillers' 1959 Annual Report is the Company's third annual report to have a polyethylene coated cover. Pellets of PETROTHENE 203-2 polyethylene resin, the coating resin used, are also shown.

In producing the cover, ten-point cover stock was first gravure printed. The printed roll was then extrusion-coated with PETROTHENE 203-2 resin.

The sheeted covers were next printed on the reverse side by letterpress with rubber plates, then the cover was embossed and stamped with gold leaf.

National Distillers and Chemical Corporation has successfully used tough, clear polyethylene coatings for its annual report for the last three years. The company foresees a growing use of polyethylene coating for publication covers, both for the feeling of quality they impart as well as for their durability.

High Greaseproofness Feature of New Coating Resin

U.S.I. has introduced a new polyethylene coating resin which reaches 100% passage of Military Specification MIL-B-121B for greaseproofness at a lower coating weight than other resins of similar melt index and density. The new resin—PETROTHENE 205-15 with a density of 0.924 and a melt index of 3.0—has excellent adhesion with a wide variety of porous and non-porous substrates.

The flow characteristics of PETROTHENE 205-15 are well suited for high-speed extrusion coating. Coatings as thin as 0.5-mil can easily be applied. Neck-in, which results in costly trim loss, is reduced to a minimum. Polymer build-up at the die is virtually eliminated. According to U.S.I. Polymer Service Laboratories, maximum polyethylene to substrate bond strength is achieved at melt temperatures of 575° F. and higher.

PETROTHENE 205-15 is unique in that it offers the wide heat-sealing range normally associated with a low-density resin, combined with high greaseproofness usually associated with higher density resins. A technical data sheet on this new coating resin may be obtained by writing to the Technical Literature Dept., U. S. Industrial Chemicals Co.

U.S.I.

Series V, No. 3

POLYETHYLENE PROCESSING TIPS

FACTORS AFFECTING ADHESION IN EXTRUSION COATING

In the polyethylene extrusion coating process, the nature of the bond between coating and substrate can be chemical, physical or a combination of both. Chemical bonding is involved almost exclusively when the substrate is a non-porous material such as foil or cellophane. With porous substrates such as paper or board stock, physical as well as chemical bonding takes place.

Physical bonding results from the absorption of the molten polymer by the substrate pores. The degree of adhesion is primarily a function of the polyethylene melt index and the surface characteristics of the substrate.

Resins of lower viscosity, which flow more freely, bond more firmly than do higher viscosity resins. The more porous the substrate, too, the better the physical bond will be.

Oxidation Improves Chemical Bonding

Chemical bonding depends on the number of carbonyl (CO) groups on the coating surface at the moment of contact with the substrate. Since carbonyl groups are formed by oxidation of the polymer, conditions which promote oxidation generally result in improved adhesion.

Heat has the greatest effect on oxidation; hence, stock temperature control is important. Figure 1 shows that increasing stock temperature produces an increase in carbonyl groups on the polymer surface. Figure 2, the curve showing the effect of stock temperature on adhesion, is almost identical.

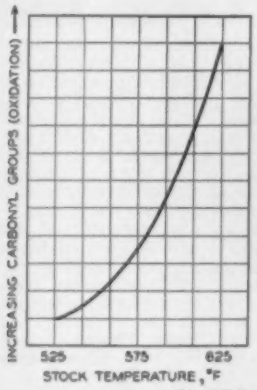


FIGURE 1

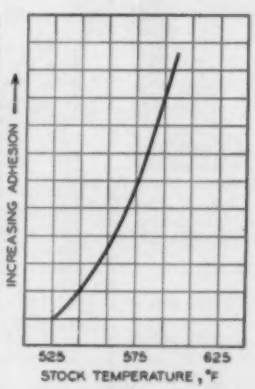


FIGURE 2

A minimum stock temperature of 575°F. is necessary for adequate adhesion in most operations. This value is based on extensive research in the Polymer Service Laboratories of U.S.I. As a rule, temperatures above this are recommended.

The operator, however, must not work at temperatures high enough to cause excessive oxidation. If he does, the polymer will be degraded badly and its heat sealability impaired. Using the above minimum value as a guide, he must determine for each application a stock temperature that will give maximum adhesion without serious degradation.

Controlling Coating Temperature

Several other operating variables affect oxidation of the polymer. Increasing the coating speed allows less time for oxidation to occur, and therefore decreases adhesion. Conversely, heavier coating weights improve adhesion by slowing the cooling time of the molten web. Preheating the substrate has the same effect.

Adjusting Coating Equipment

One measure of coating quality is uniformity of adhesion across the entire width of the substrate. This can be achieved only by careful alignment of the extrusion coating equipment. Chill and nip rolls must be parallel in the same horizontal plane, and the die must be in a plane parallel to the nip.

Pressure applied by the rubber pressure roll should be uniform across its width. And excessive pressure should be avoided since it contributes little to bond strength.

Picking the Right Resin

Good adhesion also depends on the choice of the right resins. Many resins that are excellent for film extrusion, for example, are not quite so good for extrusion coating. U.S.I. has developed the following series of "Petrothene"® resins specifically for the coating process. These resins have excellent coating characteristics and their oxidation is easy to control.

PETROTHENE® Resin	Melt Index	Density	Recommended Coating Weight (Lbs. per 3000 sq. ft.)
200-2	3.0	0.915	20 and higher
201-2	5.0	0.915	10 to 25
203-2	8.0	0.915	3 to 15

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EDITORIAL

A New Business Cycle for Molders?

A few months back, we asked Dr. Russell Akin, Assistant Director of Du Pont's Technical Services Laboratory, to write an article on "blue-sky" research on new materials. He responded with the following article, published this month as a guest editorial. Dr. Akin feels that both processors and users of plastic parts are fed up with the glowing promises of what the future holds. The low return on investment which is now being experienced by many custom molders is an indication that the economic health of many molders and extruders is far less than one would expect from the rosy picture painted of the expanding nature of our industry. Because Dr. Akin's editorial is philosophical, and since philosophies can differ widely, some readers may take issue with him. Others may agree. Your comments to the Editor are invited.

The expansion of plastics materials production in the next decade should spell a fine opportunity for growth of the custom molder, if he in turn utilizes the opportunity to become a true purchasing agent for those who may buy components or finished assemblies of plastics. The Society of Plastics Engineers was started by men who sought means to discuss and solve mutual problems. The Society has prospered as it provided engineering help to men with a variety of backgrounds and needs.

But the great number of problems and geographic spread of SPE made it impossible to provide adequate service as organized originally. To adapt to various needs, the Professional Activities Groups were formed to bring together men of similar interests, for instance in extrusion or injection molding, whether as processors or as suppliers of machinery or materials. These are working groups which provide a chance for all to stretch their minds. Yet processors aren't taking full advantage of these PAG's.

The custom molder carved a place for himself because prospective users had neither processing equipment nor knowledge to permit choice of materials. The custom molder, to keep his machines busy, had to integrate his thinking with that of his customer. Molders prospered pretty directly as they devoted themselves to advising prospective users on choice of material and design of parts and tooling. The rapid expansion of thermoset molding from 1925 to 1940, and injection molding from 1937 to 1957, were largely due to imaginative selling by custom molders determined to inform end-users on new or proven materials as well as on processing techniques.

With introduction of thermoset and then thermoplastic materials, makers of the raw materials recognized the need to deal directly with end-users to establish markets. A new cycle appears to be starting for molders. As the variety of resins increases, the prospective end-user becomes more confused as to proper choice of material and processing methods. The custom molder can be welcomed as purchasing agent for this end-user only if the processor knows the scope of resins and works closely with materials suppliers to explore promising variations in plastics materials.

Increasing costs of chemical plant expansion and greater competition among similar and different materials require these plants to operate at ever higher percent of capacity. Despite a desire to cut down on production costs, plastics suppliers will be anxious to add modifications which will serve additional markets; types will proliferate rather than standardize. In effort to shorten development time to commercially attractive volumes, materials suppliers will intensify their efforts with end-users, and once again we are entering the cycle of materials suppliers going directly to end-users to establish and enlarge markets.

Materials suppliers earnestly desire healthy and innovating processors as partners to use the expanding production. Aggressive processors who embark on deliberate programs to upgrade and update their knowledge of materials will be the ones whose reputation attracts end-users willing to pay for engineering advice and processing mastery. The custom shop which does not adopt this plan may well become a job shop which receives little beyond request for low quote on already-designed work. Materials suppliers are providing a wealth of data on design properties of their plastics. Unfortunately, custom molders as a whole are not seeking or learning to use these sales aids. Not often does the custom molder select among such literature, augment it with his own know-how, and make a missionary effort to deliver the information to prospective users of plastics parts.

This may sound pessimistic, but it is only a statement of fact of successful business life for the custom molder: Seize the opportunity to grow by appointing a capable employee as manager of materials and design data, and empower him to direct your estimator and customer; or relinquish the grasp of business knowledge for which end-users pay the premium that means profitable processing.

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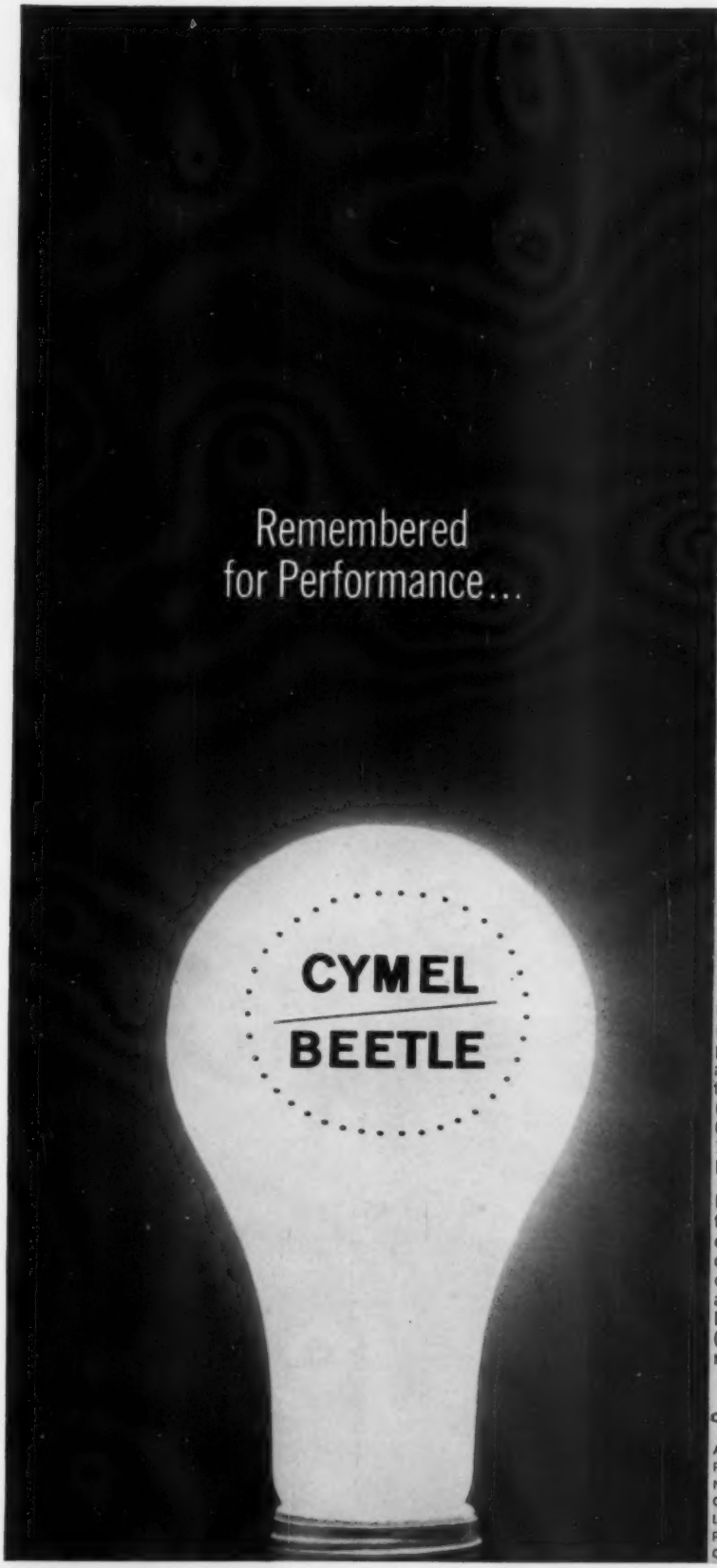

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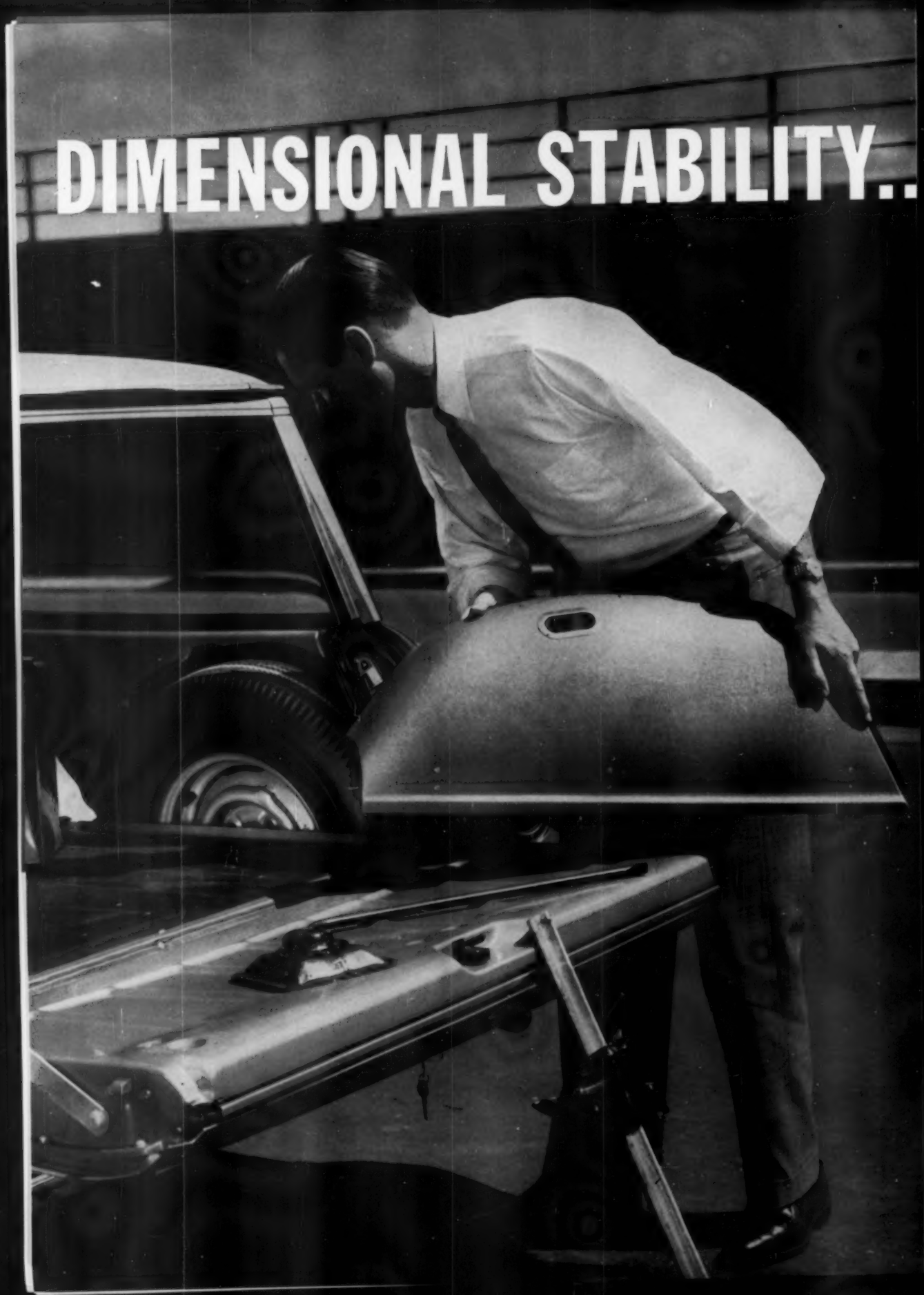
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Tensile Strength, psi	D 638	4200
Elongation, %	D 638	60
Secant Modulus, at 1%, psi	D 638	157,000
Hardness, Durometer "D"	D 676	63
Tensile Impact, ft. lbs./co. in.		160

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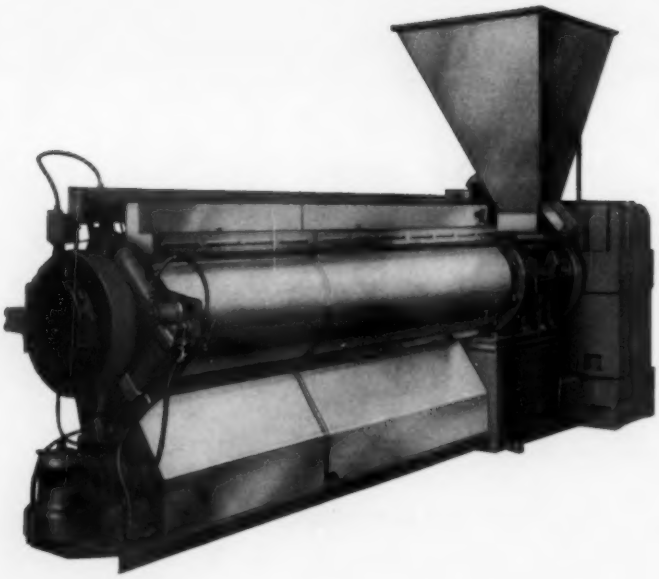

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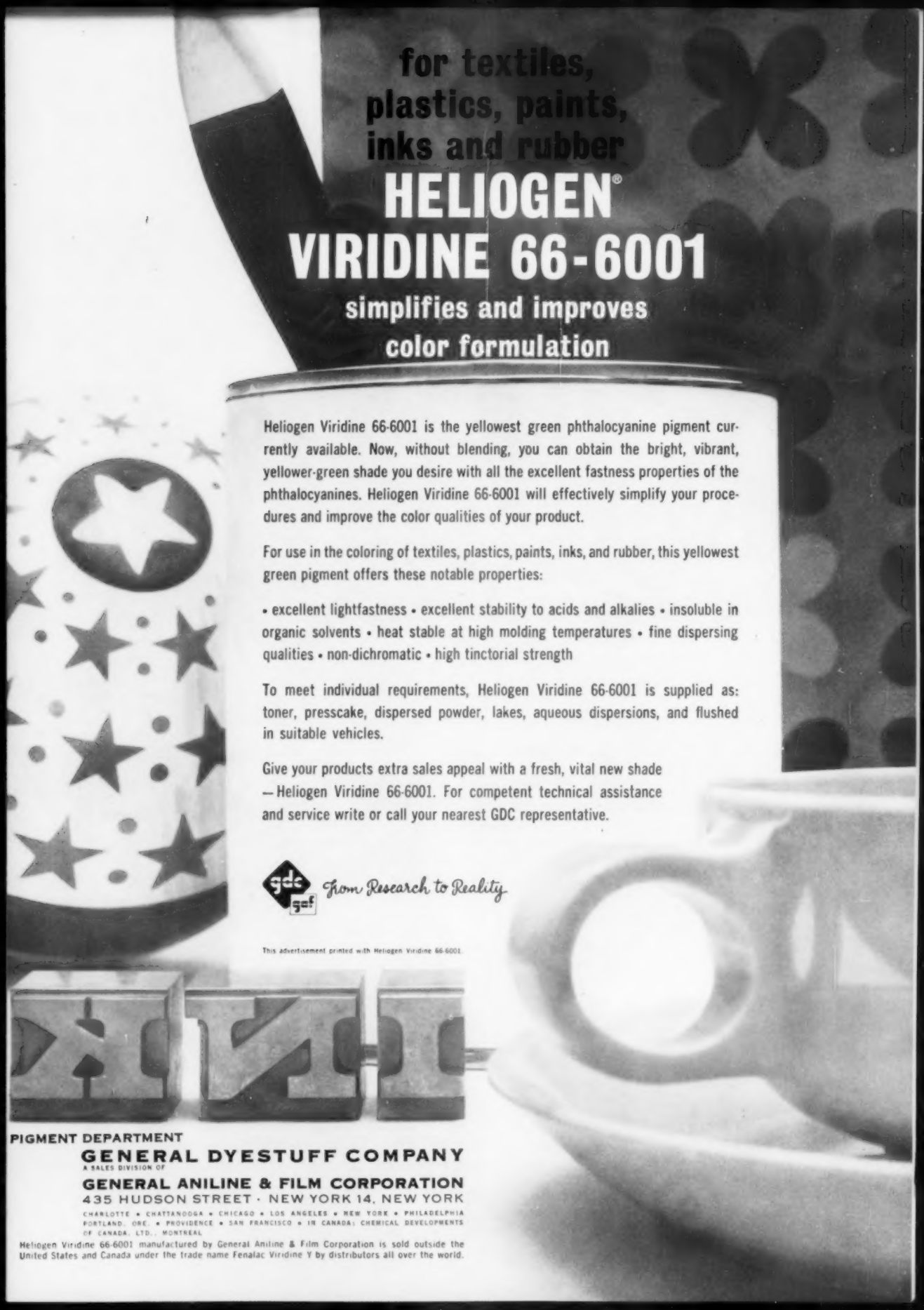
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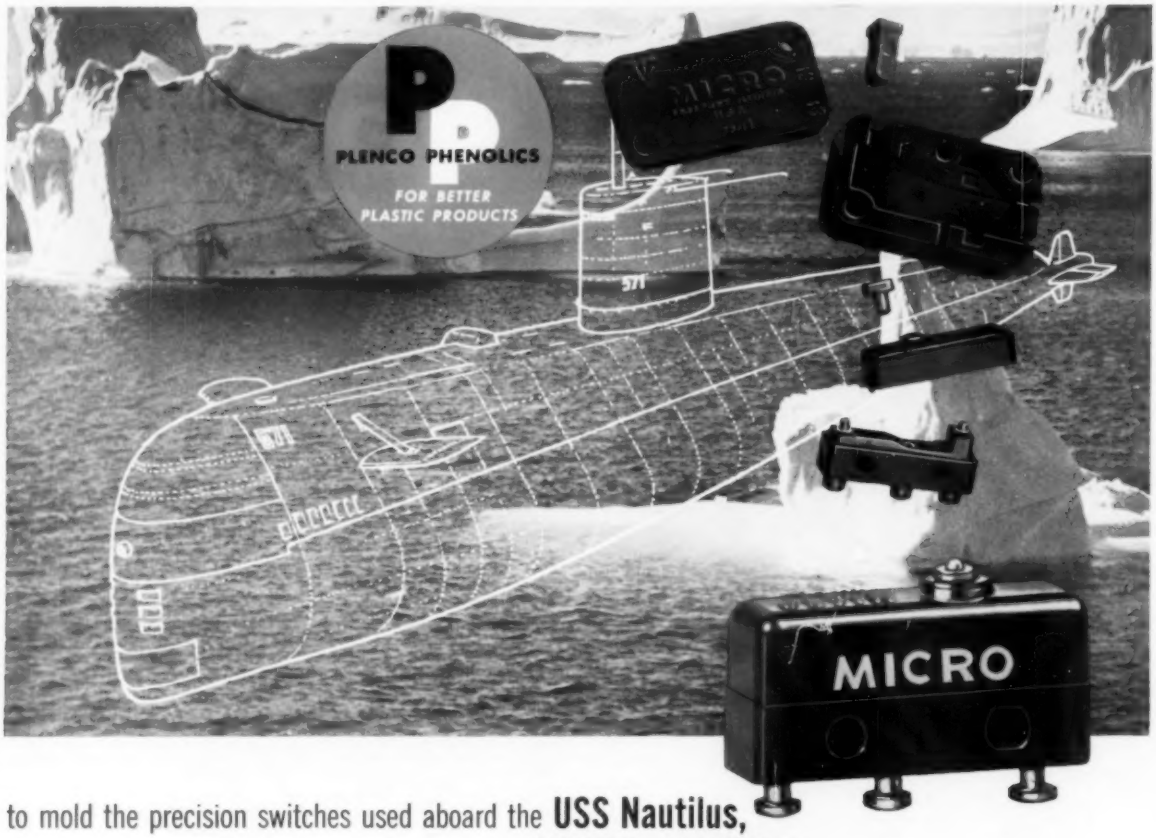

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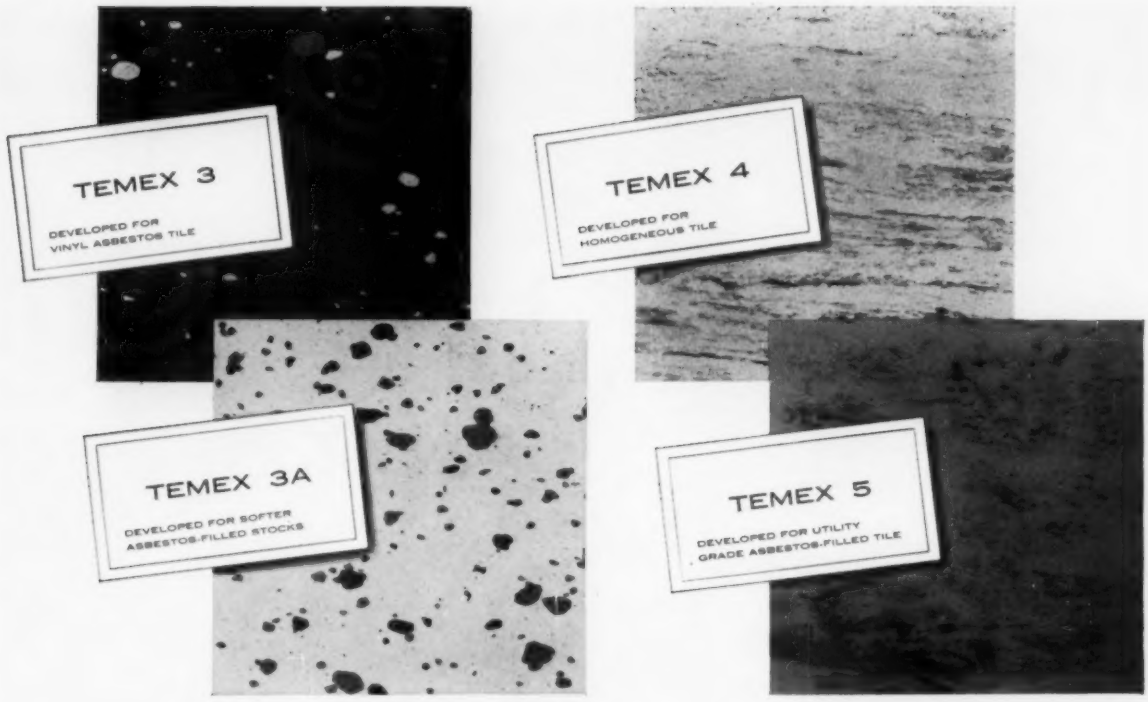

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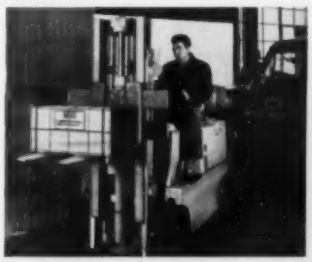

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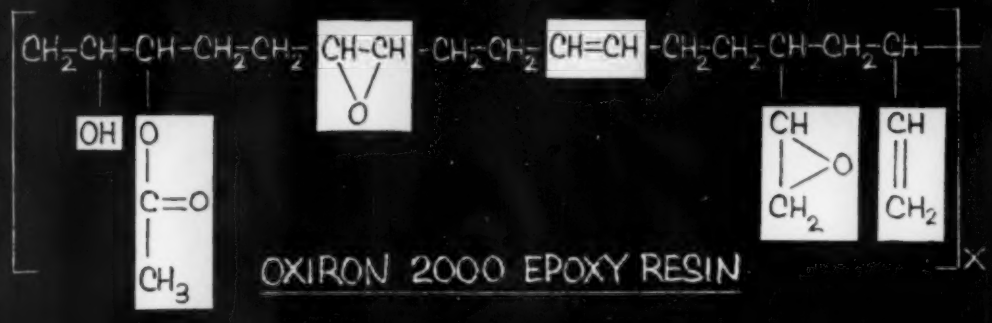
FMC ANNOUNCES VERSATILE NEW EPOXY RESINS



Schematic formula of OXIRON Resins

OXIRON Epoxy Resins Offer Multiple Reaction Sites Plus Unique Vinyl Reactivity

OXIRON 2000 Series Resins are Highly Reactive.

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OXIRON Resins Offer the Following Advantages:

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Economy: Low-cost curing agents may be used in high proportions.

Low Density: 20% lighter than ordinary epoxies–cured resins likewise have lower density.

Outstanding Chemical and Electrical Resistance: Excellent resistance to alkalis, acids, and solvents –cured resins have good electrical properties.

Superior High Temperature Performance: Combination peroxide and anhydride cures give high heat distortion point resins. The unique flatness of the heat distortion curves of OXIRON Resins translates to acceptability for practical use at temperatures ranging far above the heat distortion point itself. OXIRON Resins show superior high temperature aging.

Send for our *FMC Epoxy Data Booklet* which describes OXIRON 2000, 2001 and 2002 in detail, contains curing information and gives suggested uses. After deciding which resin will best suit your needs, we will supply laboratory samples upon request.

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To provide an outstanding visual element that would catch the customer's eye, the Florida Citrus Commission came up with a real shopper-stopper for an orange juice display...a giant, rotating Butyrate "orange," internally lighted, with skin texture duplicating the actual fruit.

Vacuum-formed in two halves from sheets of tough Tenite Butyrate plastic, and then fastened together, the sphere is 28" in diameter. Each side carries a silk-screened message.

The deep draw and sharp detail necessary in this forming made Butyrate an obvious choice. Sheet extruded of this Eastman plastic can be vacuum-formed into imaginative shapes quickly and uniformly. Fast-cycle machines can be used with no need for special preheating equipment.

Since this display piece stands amid the heavy traffic of a busy supermarket it must be prepared to take hard knocks, especially when it is disassembled to replace the lights inside. Butyrate, "the tough sign plastic," not only withstands abuse in service, but in fabrication and shipment as well, minimizing breakage and replacement costs.

Available in a range of transparent, translucent, and opaque sign colors—as well as clear transparent—easy-to-form sheet of Tenite Butyrate offers unmatched design possibilities for both indoor and outdoor applications. For more information and a list of extruders of Butyrate sheet, write EASTMAN CHEMICAL PRODUCTS, INC., subsidiary of Eastman Kodak Company, KINGSPORT, TENNESSEE.

Color and lettering are applied to the white Butyrate sheet prior to forming. Distorted lettering is used so that after the sheet is "stretched" in the vacuum-forming operation the letters assume the desired size and shape.

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BUTYRATE
an Eastman plastic

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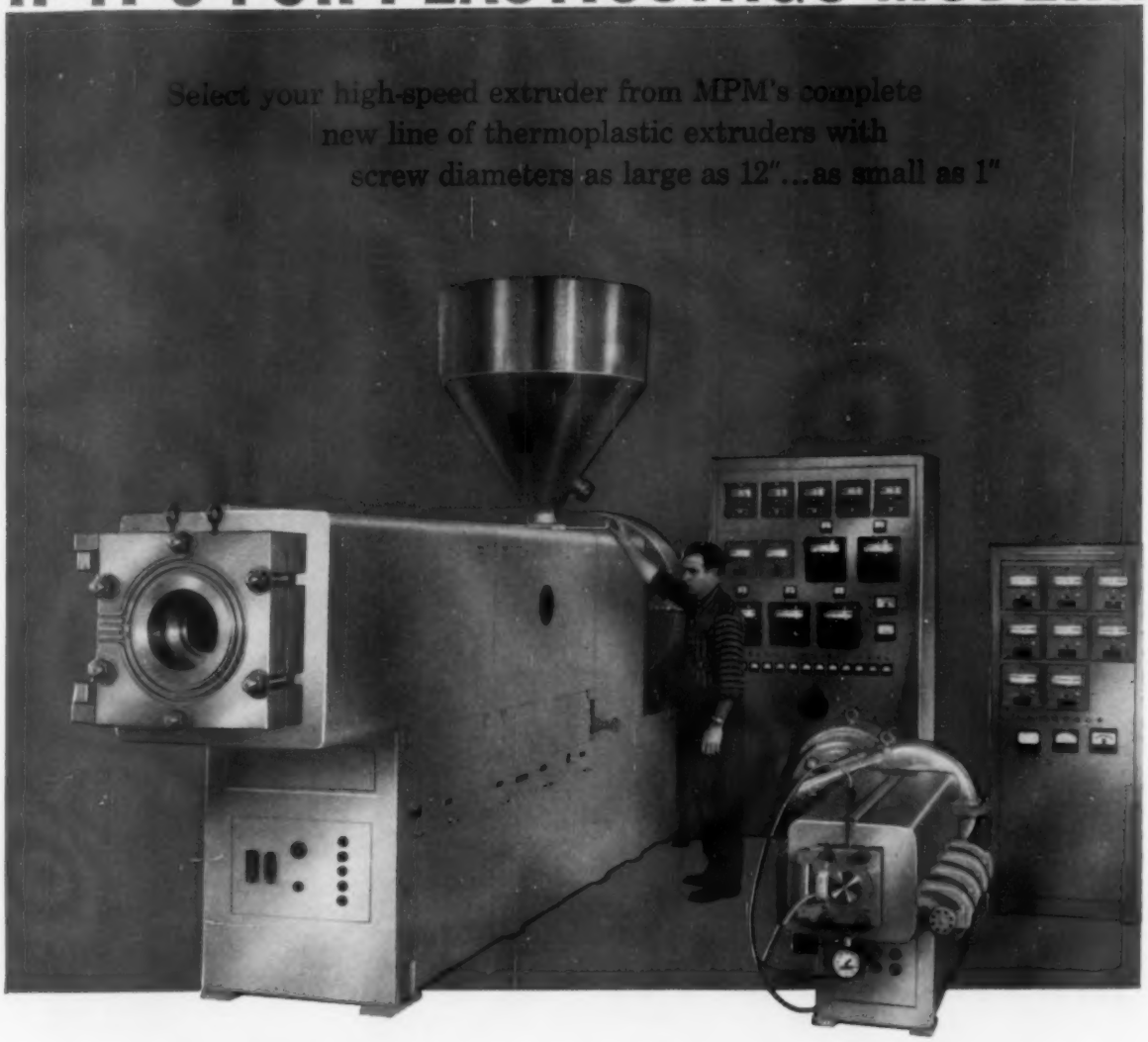
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SPECIAL FEATURE

Maintenance of Extrusion Equipment

Memo to Process Engineers:

Proper maintenance and preventive maintenance of extrusion equipment can save you thousands of dollars in rigging and operating expenses and cut down production delays

N. V. Fay

Technical Sales, Davis-Standard Division, Franklin Research and Development Corp.

Normal depreciation allows you to write off a certain number of dollars every year on capital equipment. It covers normal wear, and obsolescence due to age. But depreciation write-offs do not rightfully take into account wear due to improper operational procedures, nor can it compensate your company for down-time while equipment is being repaired.

Insurance can replace your equipment if you have a fire or explosion. But parts and labor costs to replace a burned out thrust bearing lost due to lack of lubrication, must come out of your profits. You can't buy an insurance policy for this . . . you can provide your own insurance.

A sound and faithfully executed maintenance program is your insurance policy. You can and will, reduce the cost of your operation with such a program. You will minimize down time, lower your operating costs, and provide the full operating efficiency built into the equipment.

Preventive Maintenance Starts with Installation

- Plot proposed location and provide ample clearances for removal of feed screw from the head end of the extruder, and the screw cooling piping from the rear of drive end. Study the location to make certain instrument panels are easily accessible. Give consideration to convenience of electrical, water, and drain connections.
- Level the extruder and fasten to floor. Lag screws are best for securing, but they are not always necessary. Ideal floor is concrete. Do not tighten extender to uneven floor. Shim machine to fit floor contour prior to tightening bolts.
  Remove stock feed screw and clean screw and barrel with mild solvent.
- If wire jacketing is the process, string piano wire from payoff, through extrusion head, to capstan and take-up. Put a light tension load on the piano wire; this eliminates any deflection or sag and allows alignment of each component in the processing line.
  Control panel should be mounted to minimize vibration. Instruments are protected during shipment by a shunt wire that must be removed before the instruments will work.
- Align pulleys on extruder input and drive output. Belts should have just enough tension so as not to slip on the pulleys. Make sure shafts are parallel. Over tensioning will cause abnormal belt wear and a high wear factor on the bearings.
- With extruder and drive completely wired for power, have plant electrician check to see that the drive motor is running in the proper direction.
- Each system, heating, cooling, screw temperature control, etc. should be individually checked. In the case of an electrically heated air cooled extruder, for example, bring each zone up to 150°F., verifying that the proper controller on the panel is connected to the proper zone of the extruder. Then operate the cooling blowers on one zone at a time, dropping the temperature to about 100°F. Thus, all controls can be checked for proper wiring and operation at the same time. Also make sure that instrument shuts off power at set temperature. Severe damage has occurred with defective instruments.

After installation (see box 489)— the Test Procedure

After installation, a few precautionary tests should be completed. All lubrication points should be checked and if necessary, serviced according to the manufacturer's recommendations. Generally, silent chain drives require SAE-10 weight oil and helical or herringbone gear driven equipment will use SAE-40. *For actual requirements see the nameplate or the manual on each drive.*

The screw should be removed, and the feed section and cylinder cleaned with Varsol type solvent. If the screw is coated with cosmoline it may be reinstalled. If the screw is not coated it should be cleaned with solvent, given a light coat of #10 or #20 oil, and then reinstalled. (On start-up, this lubricant will flush out of the barrel under heat with the first one or two lbs. of compound processed.) If your extruder is fitted with a Bourden type pressure gage silicone grease filled, it should be pumped full, making sure that the gage and the tube leading from the barrel is full.

All water cooling systems (feed section & screw cooling) should be turned on momentarily, checking for full flow and leaks. These systems should then be turned OFF. The extruder can now be started at the lowest possible speed and rotation of the screw checked. On the majority of extruders sold within the past few years, the screw will rotate clockwise, looking straight into the discharge end, for screws with right-hand helix.

After this is checked, the extruder can be test run ½ speed for a maximum of 3 to 5 minutes. At this time check drive belt tension, alignment, and locate any unusual vibrations. **Caution:** Do not feed compound during this test.

If it is necessary to check drive or controls when the extruder must be run at top RPM, withdraw the stock screw out of the barrel approximately 4-6". This will disengage the screw from the thrust sleeve, and allow high-speed testing of all other rotating components.

The Cold-Start Problem

Now consider the famous (or infamous) "cold-start" problem. If the barrel is full of cold compound, the possibility of extensive damage is real. Some consequences: Snapped stock screw, or split barrel, or more likely broken head parts. The belt driven extruder offers an advantage since on cold-start the belts will immediately squeal and slip offering warning to anyone to cause them to shut down immediately. The drive load-ammeter will provide an immediate indication of high-load conditions.

Start-up

Temperature controllers should be set for the desired temperatures for the different control zones of the barrel. These operating conditions will vary with the type of compound used, the material suppliers will give the specific conditions required for their polymers. For initial heat-up, it is best to allow a period of time of from 20 (up to 3½" size) minutes, to 40 (3½ to 8") minutes AFTER the barrel reaches the preset operating temperature. This gives time for such indirectly heated parts as the breaker plate to come up to temperature, and provides a thorough heat-soak of the barrel and screw.

Shut-Down

On temporary or overnight shutdown, close off the feed flow of the material, and run out the compound that is in the barrel, (except for materials that are oxidizable–see below). As the amp-loads on the drive motor drops off, shut off the temperature controllers, and stop the drive. Oxidizable materials like nylon or polyethylene may be left in the extruder barrel, minimizing air oxidation . . . (watch the next start-up!) For mate-

Use This Method to Answer the Question—When Do I Replace Extruder Screw?

Extruders screws wear. When they do, production goes down. The graph below can be used to help you decide when to replace or repair your extruder screw. To use the graph, determine the clearance between thread and barrel (δ) with an inside micrometer and measure h, the channel depth at discharge (measure root diameter and subtract from thread diameter and divide by 2). Now with δ and h values determined, you can use the equation (on graph) to solve for $\frac{\gamma}{\beta}$ vertical coordinates. This equation was developed by B. H. Maddock, Union Carbide Plastics Co., and first reported in the SPE Journal May 1959, page 433.

If your measured $\frac{\delta}{h}$ and $\frac{\gamma}{\beta}$ calculated values fall near:

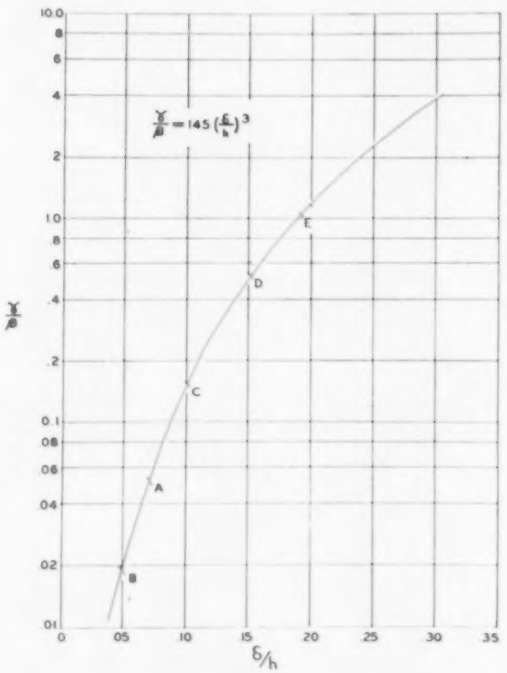
Point B— screw wear is insignificant.

Point A— Indicative of some wear, but still not too significant.

Point C— There is evidence of increased screw wear, but still not critical from a replacement standpoint.

Point D— Better specify repair or replacement.

Point E— Replace screw or build up thread to original diameter.



Three Big Headaches of Extruder Maintenance

Cold Starts

Use of improper oil and incomplete lubrication

Damage to head sealing parts

check-list

FOR

EXTRUDER MAINTENANCE

tear along perforated line . . .

The maintenance guideposts contained on this chart (inside) are basic. Being basic, they will perform a useful function for extruders, and serve as a positive reminder for doing the right thing—automatically. Proper maintenance, regularly performed, might mean the difference between down time or getting the kind of performance from your machines that was built into them.

Copies of this Chart May Be Obtained From—
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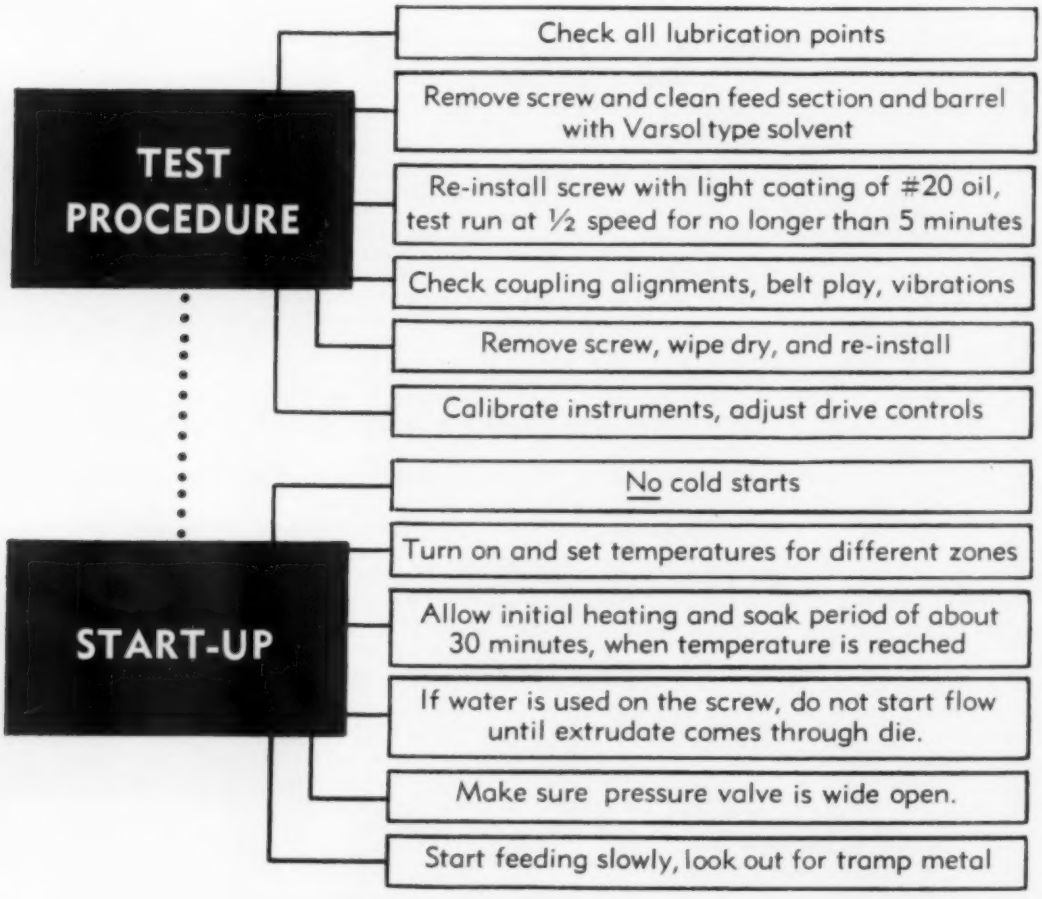
EXTRU

phase 1..... PRELIMINARY


TEST PROCEDURE
Check all lubrication points
Remove screw and clean feed section and barrel with Varsol type solvent
Re-install screw with light coating of #20 oil, test run at ½ speed for no longer than 5 minutes
Check coupling alignments, belt play, vibrations
Remove screw, wipe dry, and re-install
Calibrate instruments, adjust drive controls
START-UP
No cold starts
Turn on and set temperatures for different zones
Allow initial heating and soak period of about 30 minutes, when temperature is reached
If water is used on the screw, do not start flow until extrudate comes through die.
Make sure pressure valve is wide open.
Start feeding slowly, look out for tramp metal

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check-list FOR DER MAINTEI

phase 2 ..... OPERATING

LUBRICATION

- Proper lubrication is 90% of a good maintenance program. Use proper grade of AGMA oil
- Change oil every six months, if extruder is operated one shift daily; two or three shifts daily, change oil every 3 months
- Clean oil filters regularly
- Use only that type of oil specified by manufacturer
- Use Molycote on external fixtures such as head clamps, swing bolts, die hinges
- Check regularly for oil leakage.

EXTRUDER COMPONENTS & DRIVE

- Check screw periodically for wear (see graph in article)
- Inspect thrust section bushing periodically for wear
- Tighten all heaters periodically
- With variable pitch pulley drive, bring drive through entire speed range once a week

MAINTENANCE OF INSTRUMENTS

- Do not run thermocouple leads with any power or control wiring
- Make all connections according to proper polarity signs
- Examine thermocouples regularly for tightness and signs of wear
- Check calibration. Portable potentiometer is an ideal instrument for this purpose
- Make spare parts available for emergency servicing
- Familiarize service man with the process and particular instrument application

ck-list FOR MAINTENA

OPERATING

LUBRICATION

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ph

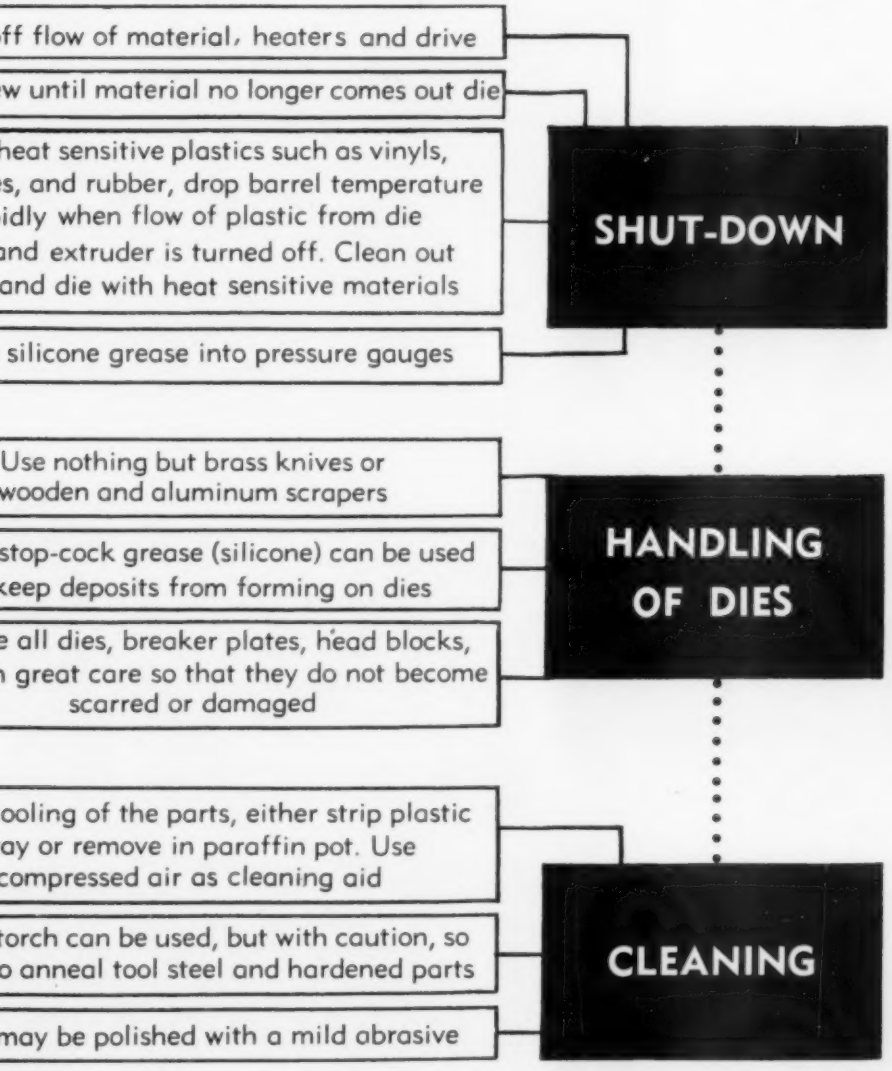
- Shut off f
- Run screw u
- For heat acetates, a rapidly stops and screw and
- Pump silic

- Use wood
- Use of stop to keep
- Handle all etc. with gre

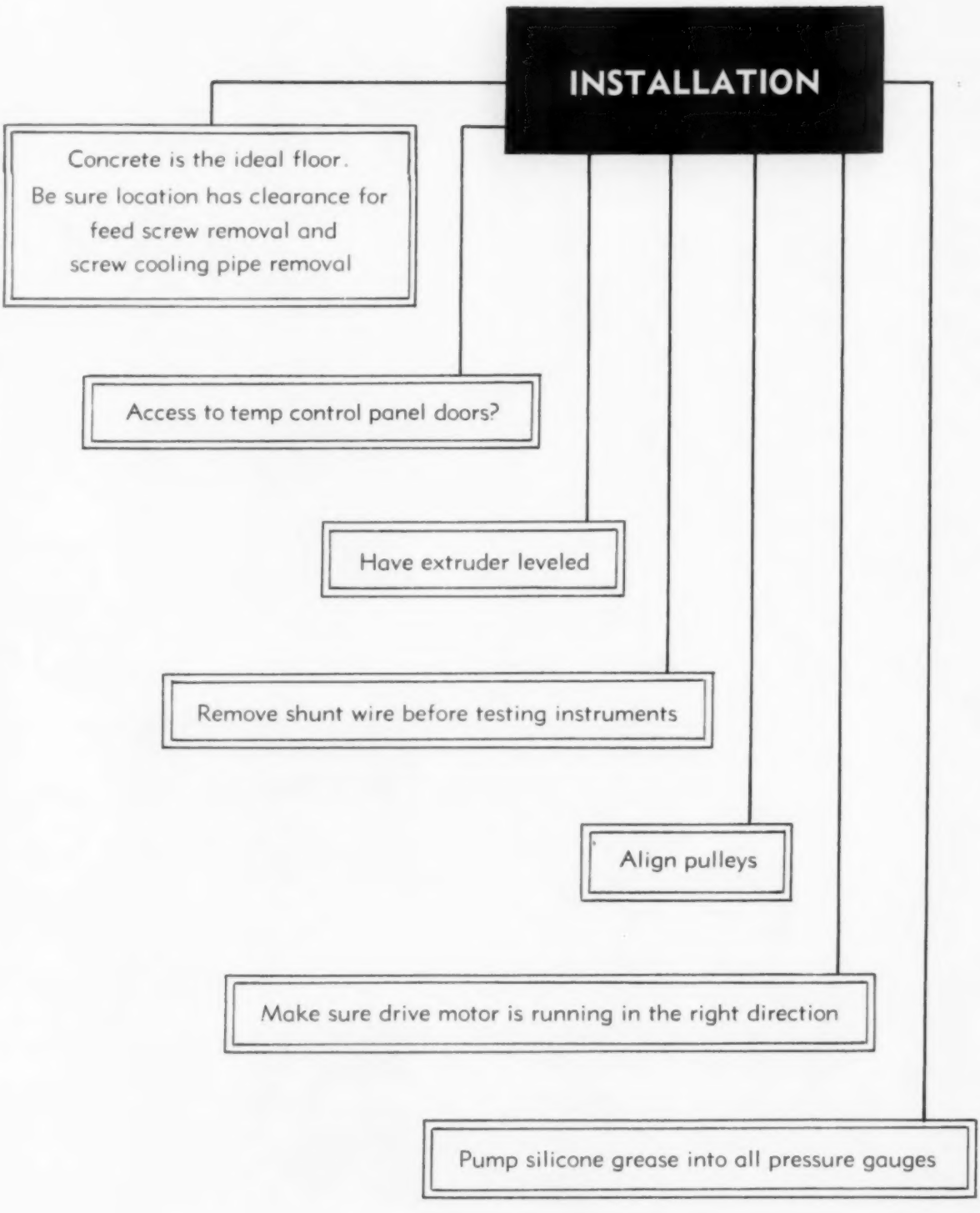
- After cooli away c com
- Hand torch as not to an
- Parts may

ANCE

phase 3 ..... SHUT-DOWN • HANDLING


ff flow of material, heaters and drive
w until material no longer comes out die
heat sensitive plastics such as vinyls,
s, and rubber, drop barrel temperature
idly when flow of plastic from die
and extruder is turned off. Clean out
and die with heat sensitive materials
silicone grease into pressure gauges
SHUT-DOWN
Use nothing but brass knives or
wooden and aluminum scrapers
stop-cock grease (silicone) can be used
keep deposits from forming on dies
e all dies, breaker plates, head blocks,
great care so that they do not become
scarred or damaged
HANDLING
OF DIES
ooling of the parts, either strip plastic
ay or remove in paraffin pot. Use
compressed air as cleaning aid
torch can be used, but with caution, so
o anneal tool steel and hardened parts
may be polished with a mild abrasive
CLEANING

FOR INSTALLATION— *See Other Side*


INSTALLATION
Concrete is the ideal floor.
Be sure location has clearance for
feed screw removal and
screw cooling pipe removal
Access to temp control panel doors?
Have extruder leveled
Remove shunt wire before testing instruments
Align pulleys
Make sure drive motor is running in the right direction
Pump silicone grease into all pressure gauges

FOR

MAINTENANCE

CHECK-LIST

SEE OTHER SIDE

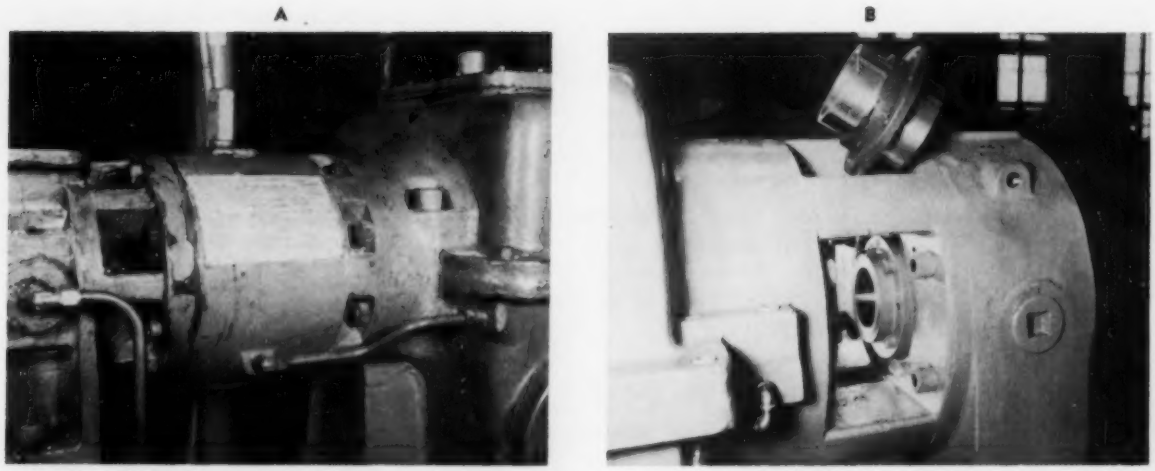


Figure 1. Designing for easy maintenance. Photo A shows the type of thrust section that requires major disassembly to service the bushing. Also, because of the direct connection it is subject to high-temperature heat transfer. Photo B shows a thrust section with an "open-gap-ring". This "gap" provides room for removal and replacement of the thrust section bushing within ½ hour, minimizing down time. The "gap-ring" also acts as a heat barrier. With newer compounds, high-temperature extrusion has become the "norm". The "gap-ring" design reduces the transfer of heat by conduction through to the reduction gear case. This in turn means longer-life cycles for gears and bearings, with a resultant longer period of operation between lubrication changes.

rials that are relatively heat insensitive, such as polystyrene and methyl methacrylate, the extruder should be run with heaters on until the barrel is emptied. Plastics that have a limited heat stability should have the barrel cooled fairly rapidly to prevent degradation of the compound in the cylinder at shut-down. **Caution:** Do not drop the temperatures too much before stopping the extruder or the compound might seize, causing damage to the screw and drive.

Caution: Never use steel tools to clean extruder or die parts. PVC may be stripped from breaker plate and die parts while hot by applying compressed air at the edge, lifting the edge as it is cooled and forcing the air under the slug. In this manner it is possible to strip the slug so it releases in one piece. A large pot of hot paraffin will melt polyethylene from head or die parts, eliminating a great deal of hand labor on cleaning. Blow torches are often used but not recommended to clean compound and they must be handled by experienced people, since it is quite easy to anneal or warp these tool steel or hardened parts. At initial use rubbing beeswax into the tips or dies will seal the minute pores and aid cleaning.

Operating Maintenance—Lubrication

The single most important factor in any extruder maintenance program is regular lubrication and using the type and weight lubrication that the manufacturer recommends both in the gear reducer and thrust bearing assembly. Generally, if your extrusion equipment is operating on one shift daily, oil should be changed every six months. Operating on two or more shifts daily, oil should be changed every three or four times a year. It is important to regularly check lubrication of bearings, reducer, and shaft seals. Another manufacturer suggests this yardstick: Oil should be changed after the first 1000 hours of operation, then periodically every 2,500 hours or sooner, if the machine is operated under dirty conditions.

Operating personnel should continually be on the lookout for oil leakage. It can mean a faulty seal or gasket, too much oil, or clogged breather. Proper maintenance remedies are application of new seals, sealing compound, or draining oil (if too much) and cleaning breather.

Operating Maintenance—General

An important aspect of maintenance is to be certain that the material is free of any tramp metal.

If band type heaters are used, it is extremely important to periodically tighten the heaters so that they fit snug along the barrel. Any dead spot will greatly decrease the life of the heater.

If the extruder is equipped with a variable pitch pulley type drive, it is important that the drive be brought through its entire speed range at least once a week. This prevents the pulleys from freezing in any one position.

As a part of your routine program have the operator check thermocouples in both barrel and head to assure tight connections. It is best to have two separate discharge lines piped to one common catch basin for the stock screw cooling, and feed section cooling. This catch basin should be open so your operator can check the flow through each system visually. Under heavy operating conditions valves may creep, either slowing or speeding the flow of cooling water. The open drains provide constant monitoring.

Cleaning Maintenance and Handling of Dies

After the extruder is shut down, and if the cylinder is to be cleaned, remove die and head while the die is still hot. One suggested maintenance procedure is to have one operator remove the screw while another cleans the other parts. The cylinder should be cleaned while still hot using copper mesh cloth. In many cases, special purging compounds can be used prior to pushing out the screw to facilitate cleaning. The screw and other parts can be cleaned with copper mesh pads or brass, and wire brushes and scrapers. **Caution:** Never use steel tools to clean extruder or die parts.

A great deal of costly damage is done in the field due to improper handling of dies, breaker plates, head blocks, and screws. The photographs (p. 498) show evidence of damage that can be done to precision parts.

Maintenance Tips on Instrumentation Problems

If measured temperature is known to be in error, check the following:

1. Open thermocouple circuit, such as a break in the thermocouple or lead wiring.
2. Thermocouple deterioration.
3. Shorts or ground in the lead wire circuits.
4. Loose connections, dirty switch contacts, or poor splicing.
5. Excessive vibration or shock.
6. Poor mechanical contact in thermocouple well.

If temperature is not at control point, check the following:

1. Adjustment of manual reset to align pointers.
2. Power input for low maximums if temperature will not rise to control point.
3. Power input for high minimums if temperature will not hold to control point.
4. Determine if instrument and control accessories are powered; check load power for open circuits and open legs in three phase circuits.
5. Measure output potential at instrument terminals to make certain that it is as specified by the instrument manufacturer.
6. Replace electronic tube, or photocell and light source.
7. Replace instrument chassis.
8. Check for excessive vibrations.
9. Measure supply for low voltages. Common low voltages to all components will cause large variations in available power to load.

As stated above in the paragraph on shut-down, use nothing but brass knives, wood or aluminum scrapers, brushes or pry-bars to remove, clean or work on any of these parts.

The die surface can be protected against oxidation deposits by applying a thin film of a stop-cock grease.

Maintenance of Instruments

Machine control centers are completely or partially wired for your machine, depending upon the manufacturer. These control panels should be mounted to minimize vibration, since extreme vibration can affect relays and contactors. Most temperature control instruments are calibrated to be mounted no further from the thermocouples on the extruder than 25'. If your installation requires mounting the panel more than 25' from the extruder, the manufacturer can recalibrate the instruments to reflect the longer thermocouple lead resistances providing full accuracy. However, caution should be used in the possible elimination of stray electrical currents. Do not run thermocouple leads with any power or control wiring. Once the control panel and its instrumentation has been properly installed, the meter shunt wires may be removed.

One of the most common errors in the installation of temperature control equipment —leading to increased instrument maintenance is the incorrect wiring of thermocouple and lead wires. Iron constantin wire is color coded. All connections must be made according to proper polarity signs, otherwise your control instrument will not work properly. Check polarity by twisting the lead wire together at the far end and then heating this junction. If the meter pointer moves upscale, it is correctly connected.

Maintenance of thermocouples requires that they be examined at regular intervals and replaced when they show signs of advanced deterioration. This inspection should be a *regular routine* even though the control instruments may be equipped with a thermocouple break protection device.

Low process costs, which of course includes maintenance and down-time costs, must include the ability of a control instrument to accurately measure and control working temperatures. This means that the instrument must be reliable and properly calibrated. A convenient way to do this is to use a portable potentiometer. Another maintenance tip to keep

A (above) Undamaged breaker plate

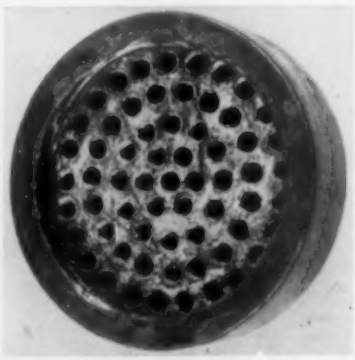


Figure 2. Using the wrong cleaning tool. Photo B (lower) shows the damage that can be done to precision parts.

in mind: Maintain a minimum inventory of interchangeable plug-in parts.

The instruments service man should familiarize himself with the process and the particular instrument application so that he will know exactly the function which the instrument is to perform. With this background, he can more easily trace any trouble to two basic problems—measure or control.

Maintenance of Blown Film Tubing Equipment

Both die and air ring must be mounted level in all directions. The air ring should not touch the die block, as it will conduct heat from the die, causing a rise in the air temperature of the cooling air going through the air ring.

Nuts, bolts, and screws and threaded parts should be coated with a good copper base screw release compound at installation. This will prevent seizing of parts due to heat. All die parts should be cleaned carefully using copper scouring pads or dry rags with any good brand of scouring powder. Scratches on die parts will be magnified and intensified on the surface of the blown film bubble.

Suggested Spare Parts List

1—set adjusting screws for die
1—set spare thermocouples
1—set spare band heaters

Nip-Roll Tower

The nip-roll tower should be positioned so the center of the nip is directly over the center of the die. The tower should be checked with plumb lines, and leveled at all four corners. The centerline of the nip-rolls over the die should then be rechecked. The tower should then be lagged in place at the floor line. At least two braces should be run from the top of the nip-roll frame to the ceiling beams to provide rigid positioning from at least two directions.

The collapsing frames (or rolls) should be checked and cleaned regularly. Dirt or rust spots will impose a drag on the bubble, marking the film. Bearings on the nip-rolls should be greased monthly and idler roll bearings lubricated with light oil every month also. Final maintenance tip on blown film equipment: Provide shielding to protect bubble from stray drafts.

Maintenance of Winding Equipment

Preventive maintenance requires that the machine be leveled and positioned to eliminate any mechanical mis-alignments. Also it must be aligned with the process equipment to attain all rolls level and parallel. Otherwise, wrinkling and poor tracking will result.

Chain drives should be adjusted to be free-running, but not excessively tight or loose. Any gearing in the winding drive train should have the proper amount of back-lash to avoid binding.

Electrical checks should be made to make sure the equipment is properly grounded. Leads should be checked to make certain they are secure. Rotation of the drives should be determined and made to correspond to the requirements of the machine.

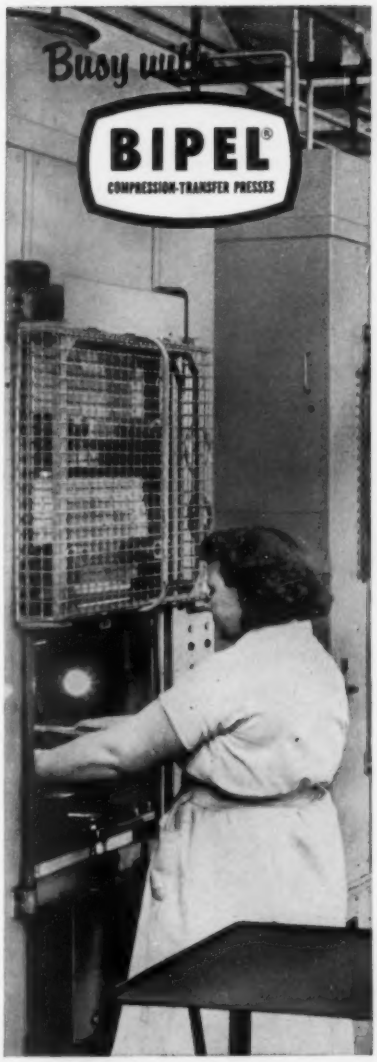
On AC motors considerable heat is usually present. Therefore the ball bearings should be packed with a good grade of high temperature grease, these should be checked, depending on the service required, every three months to once a year. With DC motors, the same basic recommendations may be followed.

Other drive components, such as gear reducers, should have the oil level maintained at the specific level with the recommended grade of oil. Once a year or oftener according to manufacturers recommendations, they should be flushed and filled with fresh oil. Chain should be brushed with medium machine oil periodically to be cleaned and lubricated. Idlers, unless the sealed type, should be greased at this time. Other bearings should be greased monthly. **Caution:** Avoid excessive amounts of grease to prevent seal damage and drag.

With systems involving air, the air must be clean and dry. Traps and filters should be installed in the lines. Where cylinders operate at moderate speeds, periodically the supply line to the cylinder should be disconnected and a few drops of air cylinder lubricant added. This will reduce the tendency to "stick-slip".

Acknowledgment

Special thanks are due H. E. Shugars, Barber-Colman Co., for preparing the section on maintenance of instruments and Al Archerton, Chief Engineer, Hobbs Manufacturing for assistance in preparing the section on winding equipment.



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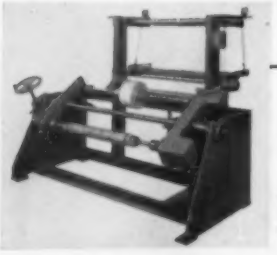

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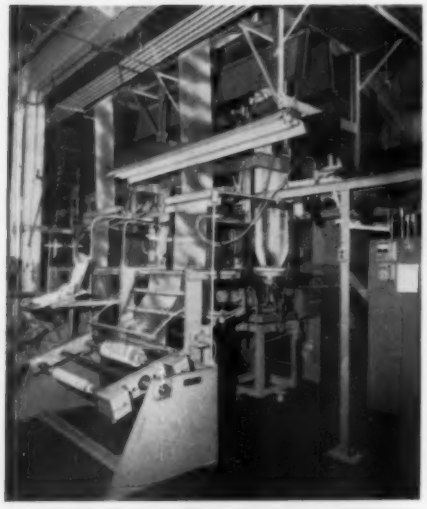

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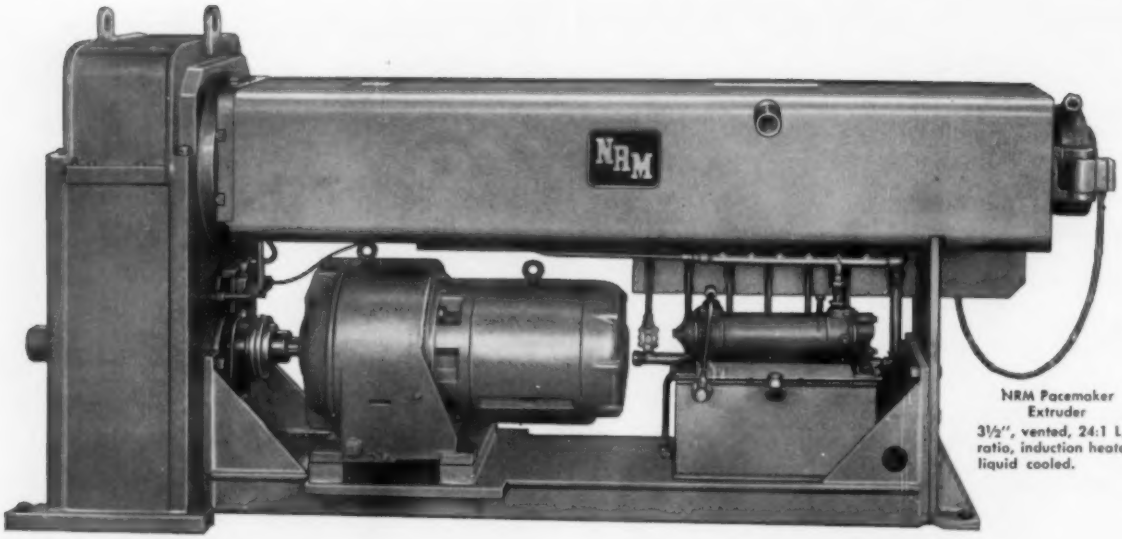

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SPEAKING OF EXTRUSION

The Extrusion of High Density Polyethylene Tubing and Profiles

The utilization of high density polyethylene profiles and tubing has just begun to be exploited in areas where stiffness, toughness, abrasion resistance and chemical inertness properties are required. Advantages are also gained in reduction of material costs per foot of extrusion due to the lower price per pound of high density polyethylene resin vs. nylon or butyrate resins. A cost savings is also available with high density polyethylene vs. rigid polyvinyl chloride. An approximate 12% increase in yield of extruded product is obtainable due to the lower density of linear polyethylene compared with polyvinyl chloride.

During the last year, considerable effort has been expended by the Grace Polymer Chemicals Division Technical Service Laboratory towards selecting proper die design, cooling methods and establishing optimum extrusion conditions. Major emphasis has been placed on the post-handling and take-off techniques because of the limited amount of information available on this phase of extrusion.

Because the melt viscosity has a direct relationship to the shape retaining properties of the extrusion in the hot draw state, a range of .2 M.I. to .4 M.I. is recommended for most profiles and tubing. This melt index range can be readily processed in most extruders having a L/D ratio of at least 15:1.

Since linear polyethylene is a highly crystalline polymer, it undergoes a phase transition slightly below the forming temperature. When the extruded hot melt is formed by the shape of the die and starts to cool in the forming equipment, it passes from a highly viscous liquid state to a highly crystalline solid state. There is a shrinkage in this phase transition, which is equal to or slightly larger than the linear contraction due to cooling. It is at this point that the shape or tube must be progressively drawn to control distortion resulting from the combination of phase transition and shrinkage due to cooling. A plot of shrinkage vs. temperature for .960 density .2 M.I. linear polyethylene is shown in *Figure 1*.

- *die design*
- *extrusion conditions*
- *post handling*

Extruder Conditions

High density polyethylene is best suited for extrusion in long barrel extruders that have a length to diameter ratio of 20:1. This results in a trouble-free feeding with minimum output variation and a more homogeneous melt of narrow temperature distribution.

Selection of the screw is also important and laboratory work has shown that a constant pitch metering type screw with four metering flights gives best results. *Figure 2* lists temperature settings used to obtain a polymer melt temperature of 330°F. A melt tem-

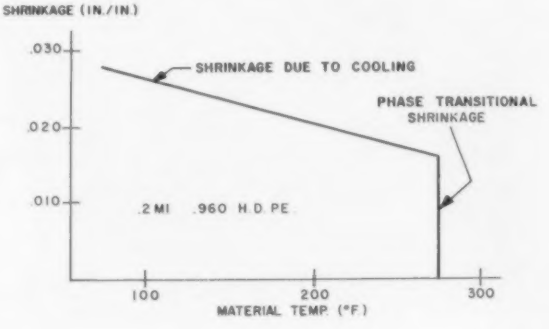


Figure 1. Shrinkage versus temperature for .960 density and .2 M.I. linear polyethylene.

perature range of 330°-350°F is desirable for the following reasons:

1. Control of sag in the air gap is kept to a minimum.
2. Higher viscosity allows a more uniform draw and reduces the sensitivity of blowout of the tube due to variations in internal air pressure.

In most cases no cooling water is required for the screw. However, the hopper feed section should be well cooled to eliminate the possibility of bridging in the extruder feed throat.

Die Design

The design of shape extrusion dies for many thermoplastic material is still a trial and error art, where experience is of primary importance. Extensive research has been done by Ernest C. Bernhardt[1], on the flow of thermoplastics through orifices. However, no attempt will be made here to treat thermoplastic flow through a die with mathematical computations, as most profiles are too complex for simple analysis. Flow calculations can definitely be used as a guide in initial die design and any deviations in actual flow can be corrected later by trial and error during the extrusion operation.

[1] Processing of Thermoplastic Materials by Ernest C. Bernhardt, SPE Plastics Engineering Series, Volume 2.

EXTRUDER	°F
ZONE 1	300
ZONE 2	320
ZONE 3	330
ZONE 4	340
HEAD	340
DIE	340

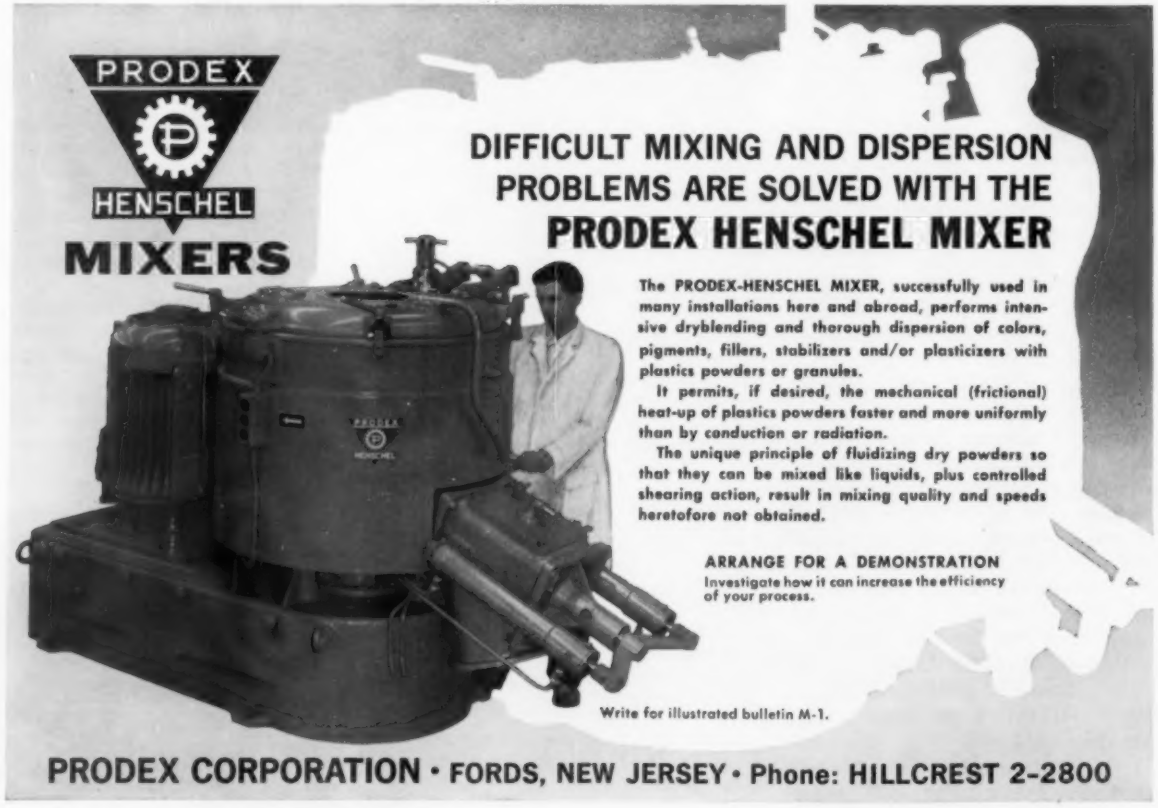
Figure 2. Temperature settings used to obtain polymer melt temperature of 330°F.

It has been found through laboratory work and actual production runs, that there are certain rules of thumb that can be followed concerning draw-ratios, land lengths and air gap distances.

Land Lengths

Land lengths, although not critical for extrusion of linear polyethylene, have a direct effect on back pressure in the die. The larger the die opening, the longer the land length required to maintain a specific back pressure for a given output and temperature. It has been found that a back pressure of 500 to 1000 pounds per square inch is necessary to overcome pressure drop through the die orifice and also eliminate weld lines or flow lines originating from the breaker plate or mandral in a cross head.

Varying the length of the land is an effective way of controlling flow in a profile die. *Figure 3* shows the actual extruded shape obtained from a profile die plate made to the exact dimensions of the specified shape. It can be readily seen that the shape produced from this die is distorted from two effects: (1) Non-uniform shrinkage due to non-uniform section widths, and (2) non-uniform flow due to the equal land thickness of the plate. A new die was made with tapered lands of approximately 30° in order to restrict the flow in the center of the shape. This restriction allowed the equalization of flow throughout the die. Trial and error methods were then used to alter the physical dimensions of the die to compensate for non-uniform shrinkage of the unequal cross-section.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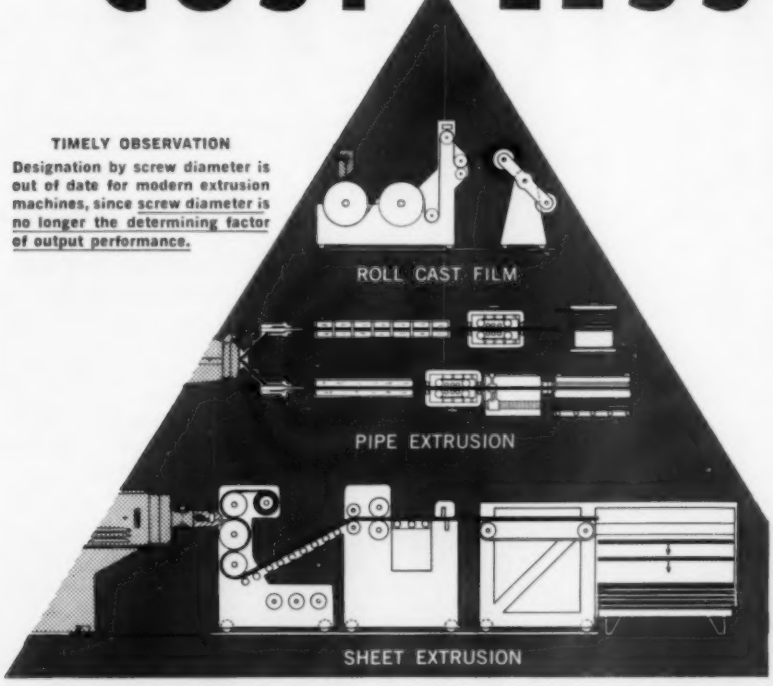

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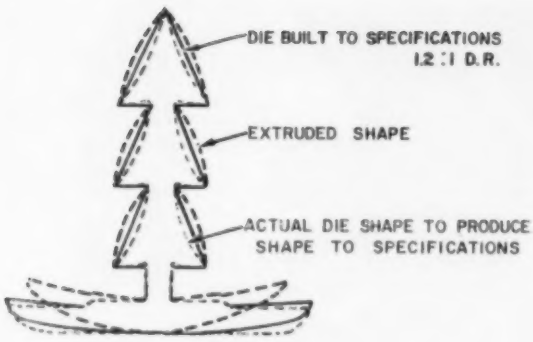

Figure 3. Actual extruded shape obtained from a profile plate made to the exact dimensions of the specified shape.

Drawdown Ratio and Air Gap

Drawdown is the drawing action applied to the hot melt as it leaves the die. Actually it is a tension to retain the shape of the hot melt in the unsupported section called the air gap. Draw ratios for linear polyethylene should be not less than 1.2 or greater than 1.5. Ratios less than 1.2 are difficult to control and cannot be successfully pressure formed. Ratios greater than 1.5 result in unequal draw rates and loss of detail in the profile.

The air gap is the distance between the die face and the first forming plate. It is here that the unsupported molten shape is drawn down to the dimensions of the first sizing plate and also acts as a seal to retain the quenching medium within the tank. The length of the draw has a direct effect on the overall dimensions of the shape. A short air gap increases the overall size, but reduces the thickness of the individual members of the profile. The converse is true with a long air gap.

The air gap also has an effect on the draw tension of the shape or tube as it is drawn through the forming plates. A long air gap due to its slow drawn-down rate reduces the forming pressure on the first sizing plate, and can cause distortion, due to lack of tension between the other forming plates located further downstream in the tank.

A short air gap has the converse effect, as the high rate of draw allows too much hot melt to pass through the first sizing plate, which creates high forming pressures in the second or third forming plates. This can result in distortion of the shape or freezing in the forming plates thus stopping the extrusion.

Post Handling

The most critical phase of shape extrusion is post-forming. *Figure 4* shows a cross section of several shapes extruded in the laboratory using the sizing plate forming method for linear polyethylene. Successful post-forming is contingent on proper design of the sizing plates. *Figure 5* shows in detail the mechanism employed for mounting the sizing plates in the quench medium. It is important that the plates be made of metal with high heat transfer properties, such as brass or aluminum. Brass is preferred to aluminum as harder alloys can be obtained, which reduces replacement due to frictional wear. Brass is also more resistant to corrosion and thus minimizes the formation of pit holes, which can mark the shape as it passes through the plate.

Most sizing plates for profiles are constructed in two pieces with the parting line in the horizontal plane. Accurate alignment of the two parts is attained by dowel pins press fitted into the bottom half and mating holes for the dowel pins drilled in the upper half. The minimum thickness of the plates is ¼", which allows for proper streamlining of the upstream side of the plate. A lead in angle of 30° has been found to be adequate with a land length of ⅛".

The size of the orifice or profile in the first plate depends upon the draw-ratio of the die. It is recommended that it be at least 10% smaller than the draw ratio of the die. This would mean that for a 1.2 draw-ratio die the first sizing plate would be 1.2 — (1.2) (.10) or 1.2 — .12 = 1.08. The second and third sizing plates are 2% larger than the specified size of the extrusion to allow for final shrinkage.

In most laboratory runs it has been found that a series of five (5) plates is optimum. The first three (3) plates perform the actual draw or progressive forming of the shape and the last two (2) plates act purely as guides to prevent warping or twisting in the final cooling stage.

It is important that the second and third sizing plates be adjustable in the axis parallel to the extrusion direction, and also be directly in line with each other at all times. This can be accomplished, (as shown in *Figure 5*) by sliding the plates on two parallel bars which are rigidly fastened to the front plate.

After the extrusion is threaded through the sizing plates, and is approximately on size, each plate is adjusted so that there is a slight amount of draw tension on the extruded shape as it passes through the orifice. When the plate orifice is completely filled with the extrudate and twisting or bending of the extrusion is not evident between the plates, proper rates of drawing have been attained.

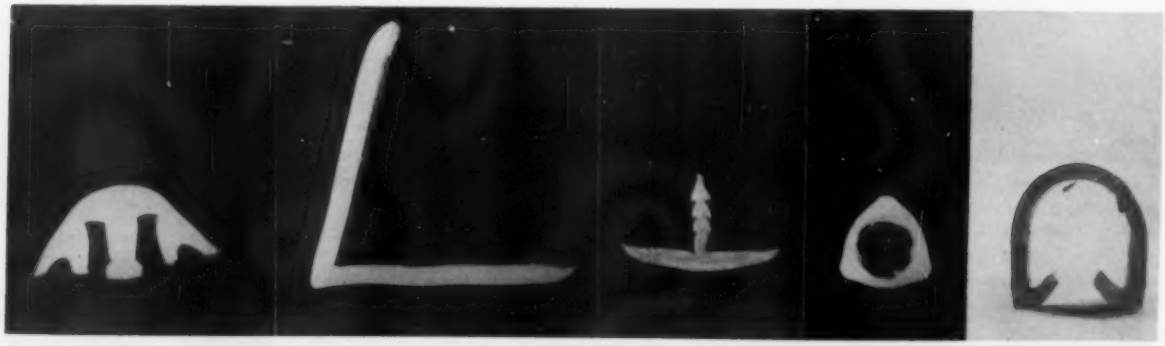

Figure 4. Cross sections of shapes extruded in the laboratory using the sizing plate forming method for linear polyethylene.

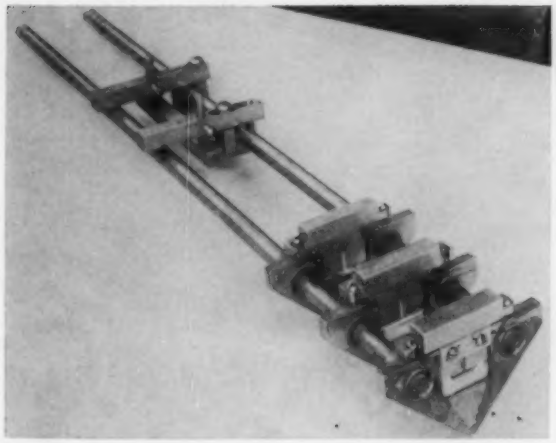

Figure 5. Mechanism used for mounting the sizing plates in the quench medium.

If the extrusion is a small diameter tube or a shape containing small tubular holes, constant volume low pressure air bled through the hole or holes will aid in maintaining the required diameter.

Take-off Equipment

Progressive drawing through sizing plates to form high density polyethylene shapes or tubing requires a steady and adequately powered take-off unit. Contact pressure on the shape and tube must be high enough to prevent slippage, but not excessive to collapse or distort the shape. Best results have been obtained with pipe haul-off equipment, having either driven belts or a series of driven rolls. Belts are prefered to rolls as the line contact obtained with belts reduces the unit pressure on the extrusion.

Conclusion

High crystallinity, the singular property which makes high density polyethylene chemically inert and rigid, makes it essential to adhere to the equipment design and techniques that have been discussed in this paper.

High density polyethylene, because of its unique properties, has opened up a new field in profile and tubing applications.

—■—

Literature References

"*Thermoforming High Density Polyethylene*", by Spill, R. F., Quinby, F. L. and Wentworth, R. A. D.—Polymer Chemicals Division, W. R. Grace & Company—Technical Papers, SPE Fifteenth Annual Technical Conference, Volume V, Page 9-1.

"*Extrusion of Plastics*", by Fisher, E. G., Plastics Institute, 1958.

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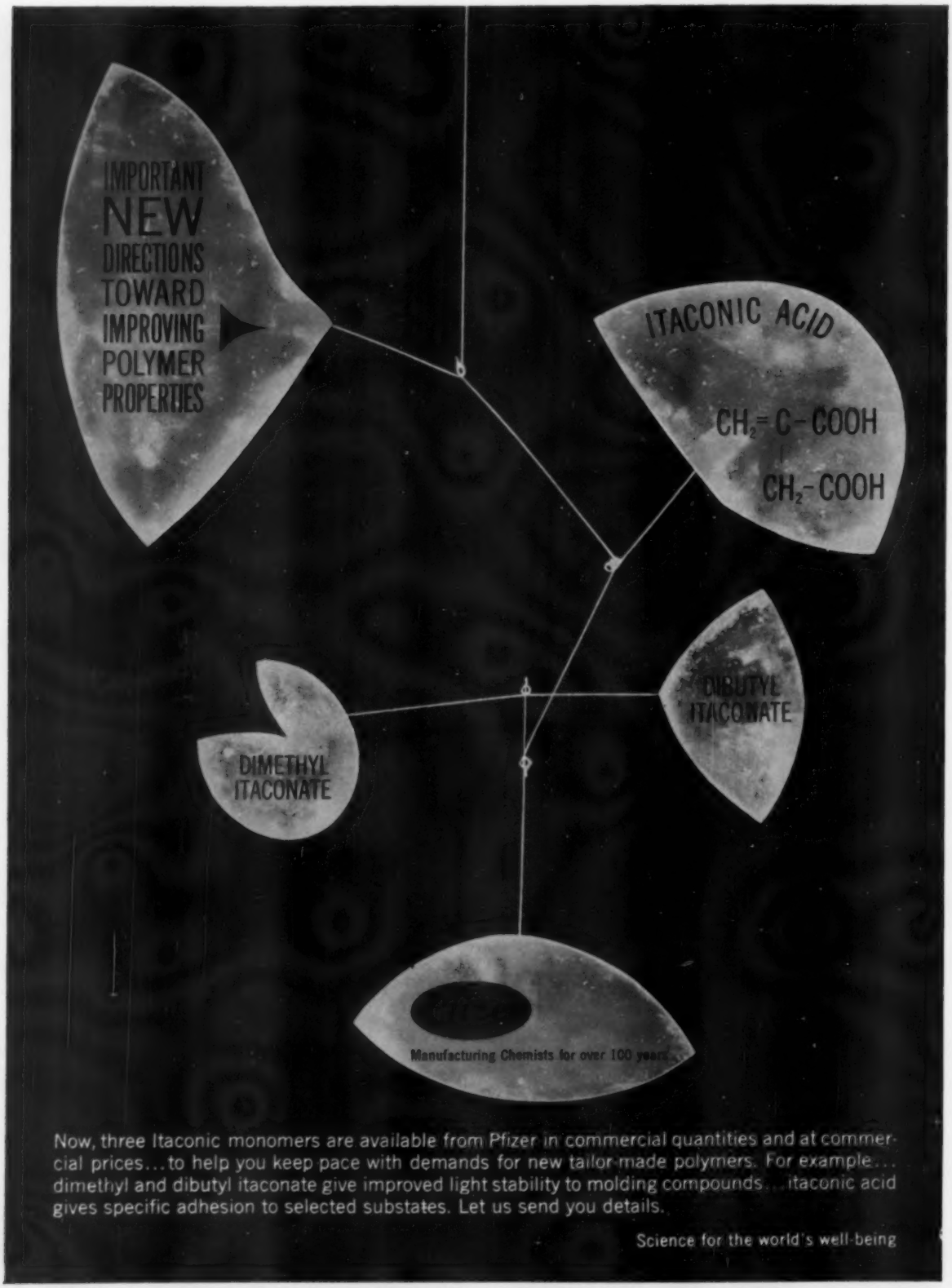

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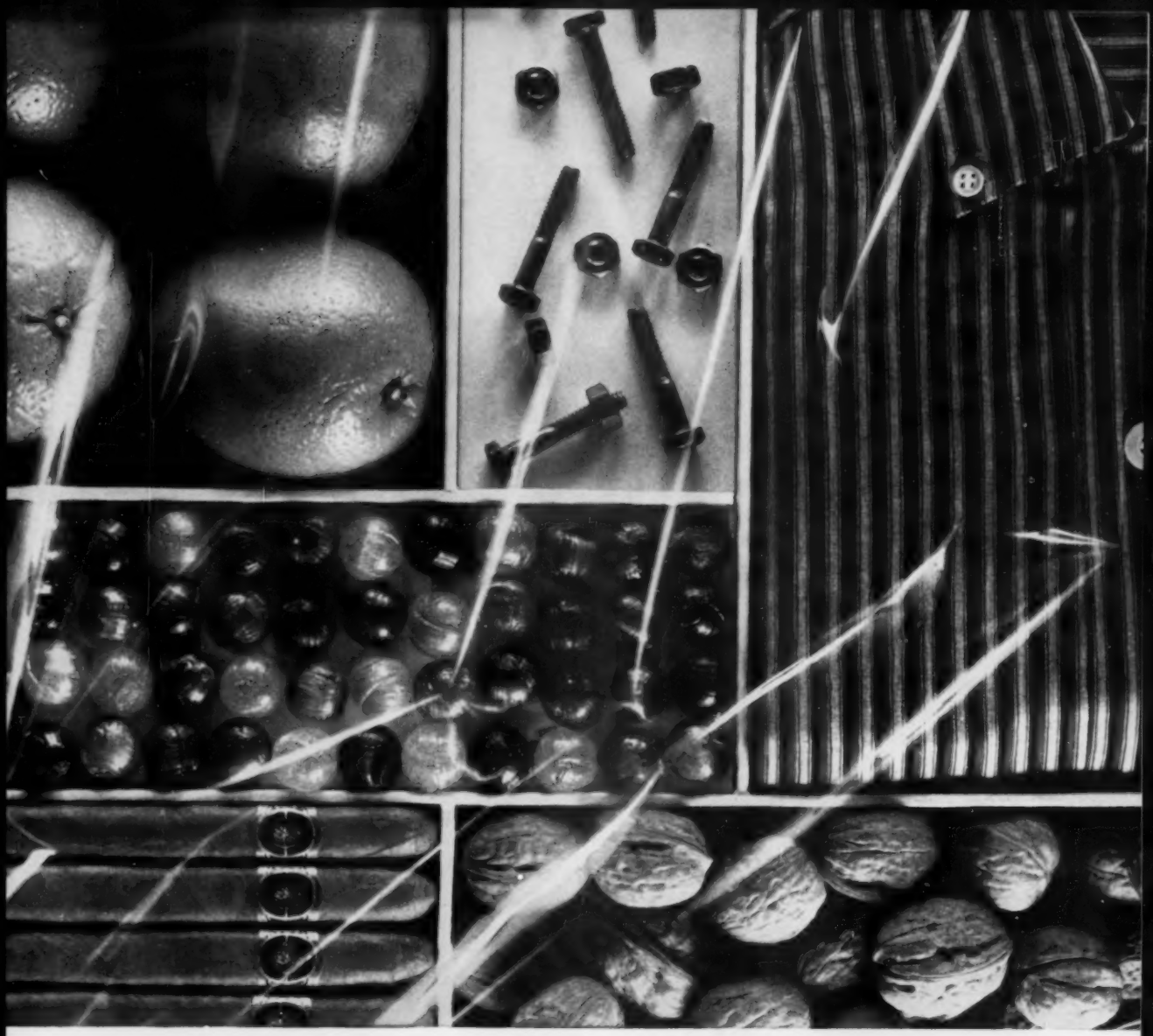

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MOLDING CYCLES

Moldability of Polypropylene

One of the most important molding properties of any resin is its relative ease of processing or moldability (flowability). This article gives flow data on a low melt index and several high melt index (Enjay's Escon) polypropylenes and compares these data with flow data for a conventional low density polyethylene, a linear high density polyethylene and two other commercially available polypropylenes.

Figure 1. Typical spiral mold being removed from the spiral mold in the 4 oz. vertical De Mattia injection press.

This article adapted from a paper presented at the 16th ANTEC —Chicago—January, 1960.

In this article, the spiral mold flow test is employed to determine the moldability of polypropylene and to compare it to the flow properties of other thermoplastic resins under molding conditions which closely simulate those used in industry. The effect of cylinder temperature, injection pressure, melt index, gate size and mold temperature on polyolefins is determined.

Moldability of high and low melt index polypropylenes is improved by increasing cylinder temperature, injection pressure, melt index and, to a lesser extent, mold temperature and gate size. This study shows that polypropylene has a wide molding range and excellent flow characteristics. These characteristics make it possible to meet requirements for the molding of thin sections or other difficult-to-mold items.

From the results reported here, it is possible to determine the proper molding conditions to mold polypropylene.

Test Procedure

A four ounce vertical De Mattia injection press with a specially designed spiral mold was used for all the molding studies (see *Figure 1*). The mold consists of a 0.125 inch diameter full round runner that can give spiral lengths up to 50 inches. Gates of 0.125 inch diameter and 0.080 inch diameter are used to transfer the molten polymers from the sprue to the spiral runner. A bronze template is used to measure the flow length, in inches, of the spiral upon removal from the die (see *Figure 2*). The

Figure 2. Spiral template for measuring the flow length of the polymer in inches.

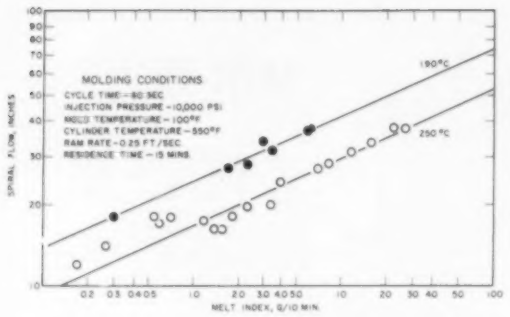


Figure 3. Correlation of spiral flow vs. melt index, polypropylene materials.

length of the spiral indicates the flow that occurs in a mold under specified molding conditions.

The spiral moldings were obtained under the following constant molding conditions:

a, Molding Cycle—40 sec.
b, Injection Ram Dwell Time—20 sec.
c, Booster Pump Time—6 sec.
d, Ram Speed—0.25 ft./sec.
e, Volume Feed—Constant
f, Constant Packing of Pellets

The other major molding variables of injection pressure, cylinder temperature, mold temperature, and gate size were varied during the investigation.

Polypropylene Processing

Effect of Melt Index and Mold Temperature on Spiral Flow of Polypropylene

The flow of a polymer increases linearly with increasing mold temperature, but the magnitude of the change is not as great as with changes in injection pressure or melt index.

A correlation of spiral flow versus melt index at 190°C. and 250°C. is shown for polypropylene in *Figure 3*. Spiral flow values were obtained for a series of polypropylenes (Escon) of varied melt index using the molding conditions shown in the figure. These values represent the polymer flow in inches, after 15 minutes residence time in the heating cylinder under constant molding conditions. The 15 minute value was chosen to insure sufficient time for the polymer melt to come to an equilibrium temperature. Values for the two commercially available polypropylenes are also included in the plot.

A conventional polyethylene (1.0 M.I.) has a spiral flow of 23 inches at the conditions given in *Figure 3*. To obtain a flow equivalent or greater than this 23 inch value, a polypropylene having a melt index of 5.0 or greater at 250°C. is required.

Means of Increasing Spiral Flow

Figure 4 shows the effects of injection pressure, mold temperature and cylinder temperature on the spiral flow of a low melt index polypropylene. Although increasing each of these variables causes an increase in polymer flow, cylinder temperature and injection pressure yield the greatest increase. The same results are

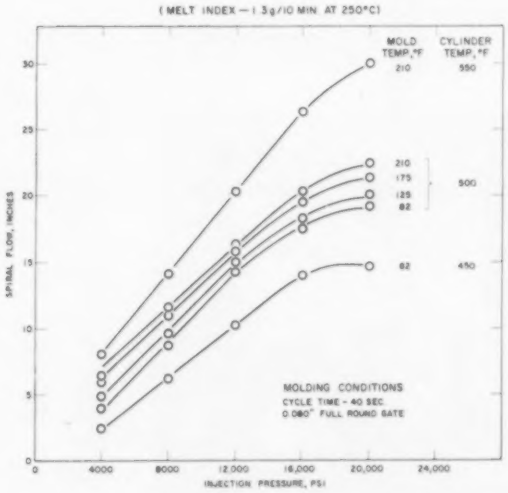


Figure 4. Effects of injection pressure, mold temperature and cylinder temperature on the spiral flow of a low melt index polypropylene.

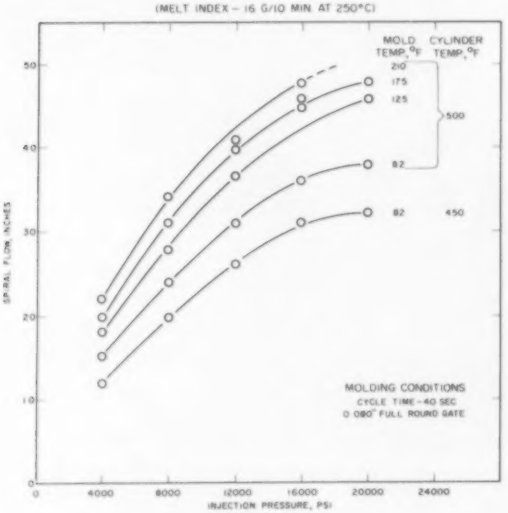


Figure 5. Effects of injection pressure, mold temperature and cylinder temperature on the spiral flow of a high melt index polypropylene.

shown for a high melt index polypropylene in *Figure 5*. Because the melt viscosity of these high melt index polymers are so low at high temperatures, they flow with very little difficulty. At cylinder temperatures of 550°F., the high melt index polymer flashed the mold under most of the mold temperatures and injection pressures covered.

Effect of Gate Size on Spiral Flow

Increasing the gate diameter in an injection mold causes an increase in the spiral flow for both high and low melt index polypropylenes as shown in *Figure 6*. This increase is less than that obtained by increasing either cylinder temperature or injection pressure. However, if the gate is made extremely small, it may well become the critical point, especially when using low melt index polypropylene.

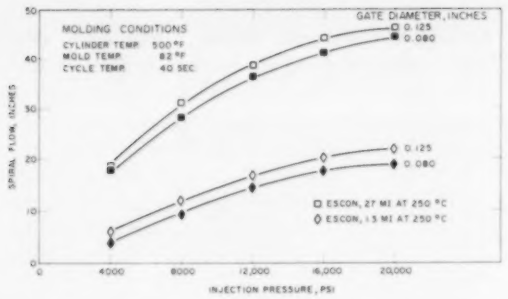


Figure 6. Effect of pressure and gate size on spiral flow of polypropylene.

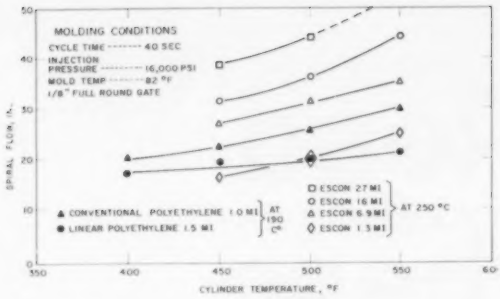


Figure 7. Effect of cylinder temperature on spiral flow of polyolefins.

This is especially true on large molded items where a large flow of polymer is needed to fill the cavity.

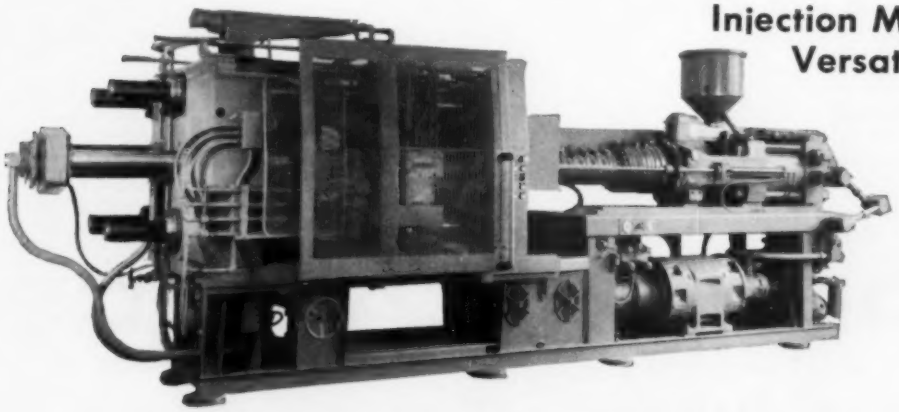
Effect of Cylinder Temperature on Spiral Flow of Polyolefins

Spiral flow increases with increasing cylinder temperature, (see *Figure 7*) a fact illustrated in previous figures. Linear polyethylene exhibits the smallest increase in flow while the increase for conventional polyethylene is intermediate between that of the low and high melt index polypropylenes. This increase in flow for the different melt index polypropylenes is particularly pronounced at temperatures over 500°F. This is due to the sharp decrease in melt viscosity of polypropylene at temperatures above 500°F.

Conclusions

The spiral flow test enables one to determine flow characteristics of polypropylene under actual molding conditions and to compare this data with flow data obtained on other polyolefins. This study shows that Escon polypropylene has a wide molding range and excellent flow characteristics. Polypropylene flow is improved by increasing cylinder temperature, injection pressure, melt index, mold temperature and gate size. From this data a molder will be able to determine the direction to go in molding conditions in order to obtain adequate melt flow to fill the cavities of his molds. He should also take advantage of the sharp decrease in melt viscosity, which results in a marked increase in polypropylene flow, at elevated temperatures.

edited by **L. Paggi,**
E. I. du Pont de Nemours & Co., Inc.



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REINFORCED PLASTICS

Heat Resistant Reinforced Laminates

This article describes the preparation of glass-reinforced laminates with excellent physical and electrical properties, using a specially-designed phenolic resin

For glass reinforced laminates requiring high heat resistance, certain phenolic resins have proved to be superior to other phenolic and nonphenolic resin systems. The physical properties of the laminate as well as the heat resistance are determined by this choice of resin. However, in addition to resin selection, possibly the most important and critical phase of the manufacture of heat resistant laminates is the postcuring cycles. Such a laminate, Micarta Grade H-5834, is presented herein and its properties shown. In addition, this laminate is compared with other glass-resin laminates and with similar laminates using different siliceous reinforcements.

Cause of Blisters and Delamination

Typical phenolic resins of the two-stage condensation or the one-stage resole generally form blisters and cause delamination during postcure. This occurs especially if the laminates have a thickness greater than ⅛". Failure normally occurs in the temperature range of 350-400°F due mainly to thermal degradation products forming blister pockets. The oxygen of the air causes further damage in spite of protective measures of wrapping in aluminum or burying in sand. This phenomena, more noticeable in the two-stage phenolic system, is caused by the release of thermal degradation products at these temperatures. These degradation products have been identified as free phenol, formaldehyde, entrapped solvents, water, and low molecular weight by-products of the curing reaction. These products, it is believed, act as solvents and the destructive damage is caused by the

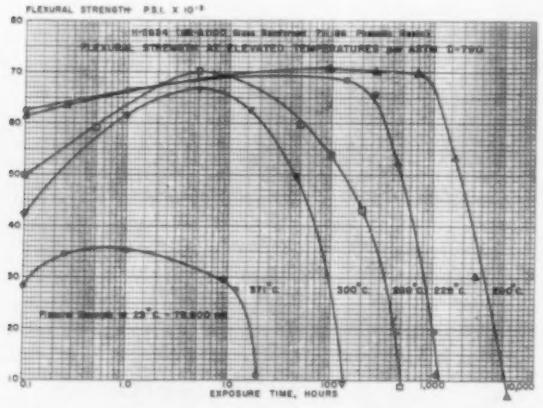

Figure 1. Flexural strength at elevated temperatures —micarta grade H-5834.

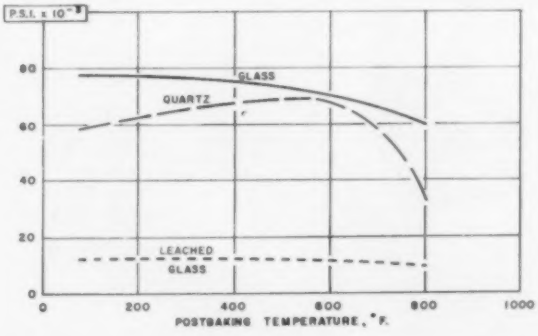

Figure 2. Flexural strength at 75°F—7 H 186 phenolic resin laminates. See page 514 for discussion

This article adapted from a paper presented at the 16th ANTEC—Chicago—January, 1960.

ELECTRICAL PROPERTIES OF GLASS—H.T. PHENOLIC LAMINATE

PROPERTY	METHOD	CONDITION	VALUE	UNIT
DIELECTRIC STRENGTH, PERPENDICULAR, SHORT TIME	D-229	C-48/23/50 TESTED IN 23°C. OIL	500	VOLTS / MIL
DIELECTRIC BREAKDOWN, PARALLEL, SHORT TIME	D-229	D-48/50 TESTED IN 23°C. OIL	>50	KILOVOLTS
DISSIPATION FACTOR AT 1 MEGACYCLE	D-150	D-24/23	0.018	- - -
DIELECTRIC CONSTANT AT 1 MEGACYCLE	D-150	C-48/23/50	6.1	- - -
VOLUME RESISTIVITY	D-257 D-1371	C-96/35/90 T-35/90	5×10^6	MEGOHM-CM.
SURFACE RESISTIVITY	D-257 D-1371	C-96/35/90 T-35/90	1×10^6	MEGOHMS
ARC RESISTANCE	D-495	C-48/23/50	185	SECONDS
WATER ABSORBTION	D-570	E-1/105 + D-24/23	0.12	PERCENT

MICARTA GRADE H-5834

hot solvent's action upon the cured resin binder. Thus, the interlaminar bond is weakened and blisters can form at relatively low vapor pressures.

Blister formation in the phenolic laminate is caused to a lesser extent by low molecular weight gaseous degradation products such as H_2O, NH_3, HCHO, CO_2 and CO.

Other types of thermoset resins may not show this behavior. A melamine-glass fabric reinforced laminate of 1" thickness was postcured to 500°F without delamination due to blistering effects. The melamine laminate lost weight as gaseous products of low molecular weight were driven off. Because liquid degradation products were not formed to act as solvents at elevated temperatures, the laminate remained intact.

The phenolic resin used to make the various laminates described in this paper was designed to have a minimum amount of destructive components forming at the postcuring temperature. Emphasis upon means of protection of these laminates from the destructive action of oxygen is also paramount, in this regard, thus insuring a good heat resistant laminate.

Preparation of Laminates

Standard procedures are used in the manufacture of the heat resistant laminates. No. 181 weave glass fabric with A-1100 finish (a gamma aminoproply-triethoxysilane) is impregnated with the specially developed phenolic resin varnish in a 100 ft., two-zone, horizontal treater. The resin content is held to 30-35% and the flow* to 2-5% with a volatile content (10 minutes, 150° C) of 1-3%. The A-1100 finish was selected for its better heat resistance with this particular system. Chemically leached and fired glass fabrics and pure quartz fabrics for the comparative laminates were also impregnated in a similar manner.

* Flow is the weight loss as % resulting from resin flow from a 6" x 6" laminate pressed at 250 psi and 175°C for 5 minutes.

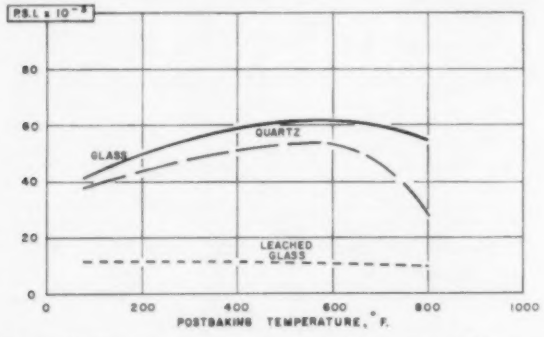

Figure 3. Flexural strength at 500°F—7 H 186 phenolic resin laminates.

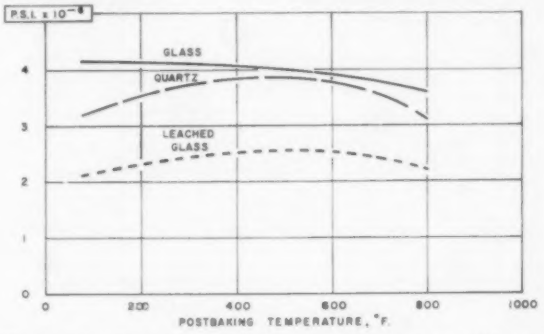

Figure 4. Flexural modulus at 75°F—7 H 186 phenolic resin laminates.

The molding operation is carried out by weighing the proper amount of treated material for a given thickness and pressed at 250 psi for ½ hour at 325°F and 1 hour at 360°F. The laminates must be protected from atmospheric oxygen during the post-curing operation. Satisfactory protection can be obtained by interleaving up to ten ¼" laminates with aluminum foil, wrapping the pack with foil and finally encasing the package in a sand bath. The assembly is then placed in an oven for postcuring. The desired cycle is obtained by a programming controller; a typical cycle is as follows:

(a) 18 hours at 250°F
(b) 7-8°F/hour rise for 8 hours (250-310°F)
(c) 0.9-1°F/hour rise for 96 hours (310-400°F)
(d) The oven is shut off and the assembly allowed to cool to room temperature before unpacking.

The electrical and physical properties of Micarta Grade H-5834 glass phenolic laminate are on pages 519 and 520 respectively. The flexural strength of this laminate at various aging times and temperatures is shown in *Figure 1*.

Comparison of Glass-, Leached Glass- and Quartz-Reinforced Phenolic Laminates

Equivalent laminates were prepared using the high temperature phenolic resin on glass, quartz and leached glass reinforcements. All contained 30-35% resin and were laminated under similar conditions.

A special technique was used to postbake the laminates for these comparative tests. Three specimens each of glass, quartz and leached glass laminates were individually wrapped in aluminum foil and packed with dry sand in a closed metal container. Four such containers were prepared. Each container was thermocoupled, wrapped in foil and placed in a muffle furnace. The furnace temperature was increased 50°F/hour to 500°F, then at the rate of 25°F/hour to 800°F. One container was withdrawn as the laminate temperature reached 500, 600, 700 and 800°F.

Flexural strength and modulus was determined on each of the laminate types postbaked at each of the four temperatures as well as on non-postbaked specimens. Samples were tested both at 75°F and at 500°F (after heating for ½ hour at the testing temperature). This information is graphically presented in the *Figures 2 through 5*. *Figure 6* shows the loss in weight of the specimens during the postcuring cycle.

PHYSICAL PROPERTIES OF GLASS-H.T. PHENOLIC LAMINATE

PROPERTY	CONDITION	VALUE
FLEXURAL STR.	C-96/23/50	74,000 PSI
	D-720/23	72,000
	E-0.5/260*	59,000
	E-100/260*	45,000
FLEXURAL MOD.	C-96/23/50	3.7×10^6 PSI
	D-720/23	3.9×10^6
	E-0.5/260*	3.0×10^6
	E-100/260*	3.0×10^6
TENSILE STR.	C-96/23/50	50,000 PSI
	D-720/23	51,000
	E-0.5/260*	46,000
COMPRESSIVE STR.	C-96/23/50	62,000 PSI
	D-720/23	57,000
	E-0.5/260*	39,000
IZOD IMPACT STR.	COND. "A"	15.0 FT. LB/IN.
BARCOL HARDNESS	C-96/23/50	81
BONDING STR.	COND. "A"	2,000 LBS.

*TESTED AT 260°C.

MICARTA GRADE H-5834

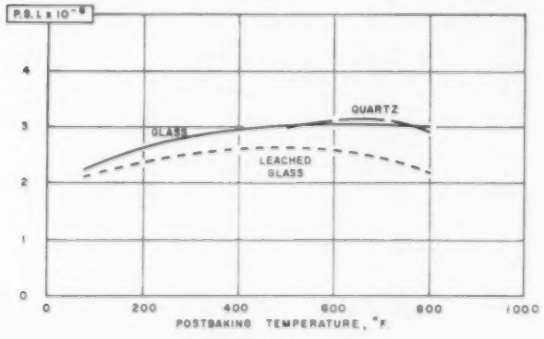

Figure 5. Flexural modulus at 500°F—7 H 186 phenolic resin laminates.

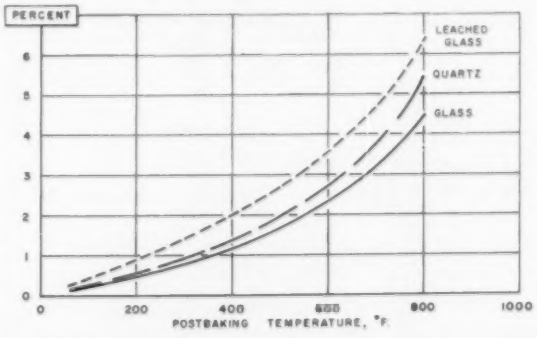

Figure 6. Weight loss—7 H 186 phenolic resin laminates.

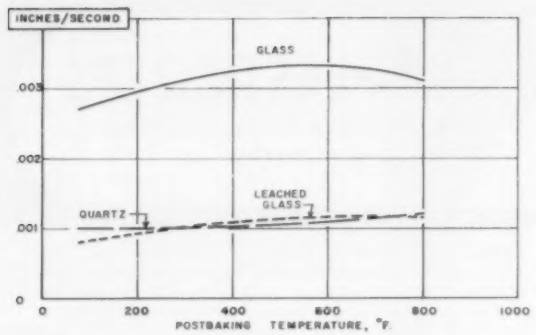

Figure 7. Erosion rate—7 H 186 phenolic laminates.

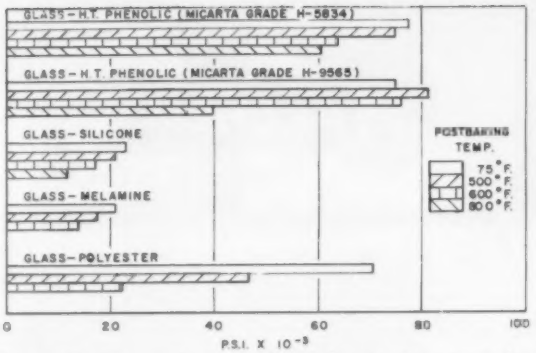

Figure 8. Flexural strength of laminates, tested at room temperature.

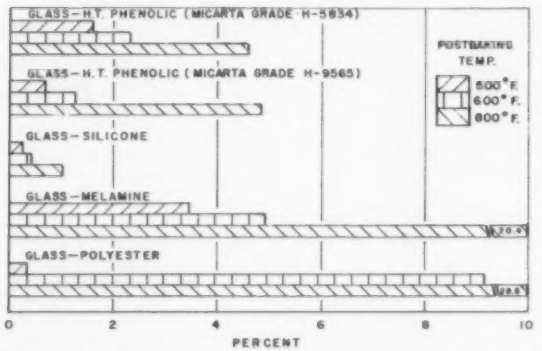

Figure 9. Weight loss of laminates, tested at room temperature.

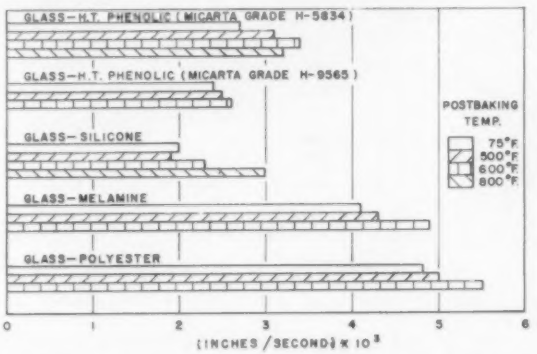

Figure 10. Erosion rate of laminates, tested at room temperature.

An interesting aspect of heat resistance in laminates is that of ablation, or erosion, resistance. To obtain an indication of how these various laminates might react to an ablative condition, the laminates were subjected to a neutral oxyacetylene flame and the burn-through time recorded. The flame was produced from a standard #6 tip using 7 psi acetylene and sufficient oxygen to produce a neutral flame, which is around 6000°F. The torch was held in a fixture so that the tip was 1¾-1¾" from the laminate. The erosion rate in inches/second was calculated from the above and is shown in *Figure 7*. It is interesting to note that when this same test was applied to stainless steel and hard maple wood, the resulting erosion rate was 0.0042 and 0.0125"/second respectively. These are four and twelve times greater than the best erosion rate determined on the quartz-reinforced laminate.

Experimental Results

The flexural strengths, weight loss and erosion rates of other resin glass laminates were determined and compared with phenolic glass laminates. *Figure 8* shows the flexural strength of the various laminates, measured at room temperature after baking to 500, 600 and 800°F. Two phenolic laminates, including Micarta Grade H-5834, a silicone-, a melamine- and a polyester-glass fabric laminate were investigated.

Figure 9 shows the weight loss of the various laminates when postbaked at 500, 600 and 800°F. The lowest weight loss occurs in the silicone laminate while the greatest amount occurs in the melamine and polyester laminates.

(continued on page 523)

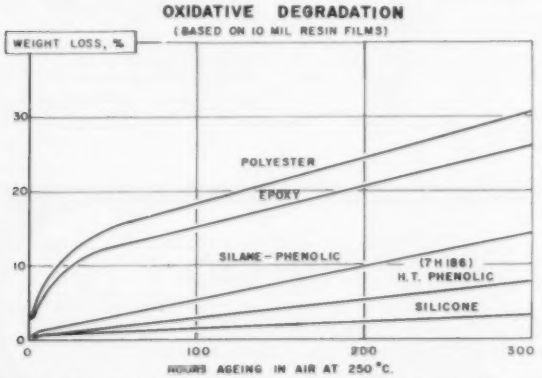

Figure 11. Oxidative degradation (based on 10 mil resin films).

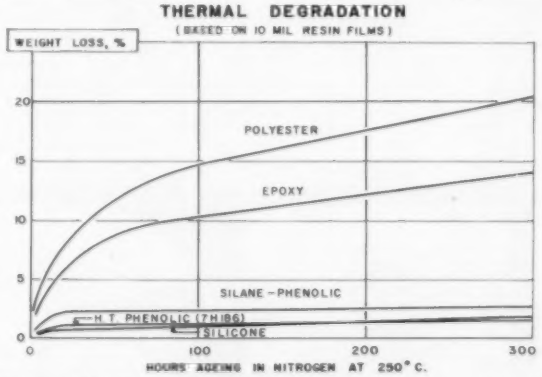

Figure 12. Thermal degradation (based on 10 mil resin films).

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Plasticizer	Specific Gravity 25°/25°C ±.003	Viscosity 25°C, cps	Compatible With	Outstanding Characteristics
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Dibutyl Sebacate	0.935	7.9	Vinyl Resins, Cellulose Acetobutyrate, Synthetic Rubbers, Rubber Hydrochloride, Polystyrene, Polymethyl Methacrylate.	Low Temp. Flexibility, Excellent Aging Qualities, Non-toxic
Dimethyl Sebacate	0.986*	3.54 @ 30°C	Vinyl Resins, Synthetic Rubbers, Cellulose Nitrate, Cellulose Acetobutyrate, Acrylic Resins.	High Solvency and Efficiency, Wide Compatibility
Dioctyl Sebacate	0.913	17.4	Polyvinyl Chloride and Copolymers, Polyvinyl Butyral, Synthetic Rubbers, Cellulose Nitrate, Cellulose Acetobutyrate.	Low Temp. Flexibility, Low Volatility, Good Electricals
Dicapryl Phthalate	0.972	55	Polyvinyl Chloride and Copolymers, Polyvinyl Butyral, Synthetic Rubbers, Cellulose Nitrate, Cellulose Acetobutyrate.	Highly Compatible, Low Volatility, Excellent Viscosity and Stability
Diisodecyl Phthalate	0.965	65	Vinyl Chloride Polymers and Copolymers, Polyvinyl Acetals, Cellulose Nitrate, Cellulose Acetobutyrate, Chlorinated Rubbers.	Low Volatility, Good Electricals
Dioctyl Phthalate	0.983	57	Vinyl Chloride Polymers and Copolymers, Polyvinyl Acetals, Natural and Synthetic Rubbers, Cellulose Nitrate, Cellulose Acetobutyrate.	Highly Compatible, Good Flexibility
Isooctyldecyl Phthalate	0.973	68	Vinyl Chloride Polymers and Copolymers, Polyvinyl Acetals, Natural and Synthetic Rubbers, Cellulose Nitrate, Cellulose Acetobutyrate.	Improved Flexibility, Permanence, Good Electricals
Dioctyl Adipate	0.924	21	Polyvinyl Chloride and Copolymers, Polyvinyl Butyral, Natural and Synthetic Rubbers, Cellulose Nitrate, Cellulose Acetobutyrate.	Low Temp. Flexibility
Butyl Stearate CP	0.857/0.86	9.1	Natural and Synthetic Rubbers, Cellulose Esters, Polystyrene, Polyvinyl Butyral: partly compatible with Polyvinyl Chloride and Nitro Cellulose.	Lubricity, Abrasion Resistance, Low Cost, Non-Toxic
Butyl Oleate, distilled	.8685/.869 @ 20/20°C	7.2	Most Natural and Synthetic Rubbers, Polystyrene, Cellulose Nitrate, Ethyl Cellulose.	Low Temperature Flexibility, Primary Plasticizer for Chloroprene, low cost
®Harflex 300	1.096	1400 @ 100°F/cs	Polyvinyl Acetate, Cellulose Acetobutyrate, Nitrocellulose, Ethylcellulose, Polymethyl Methacrylate.	Non-Migratory, Fast Processing Low Temp. Flexibility
®Harflex 325	1.100	2000 @ 100°F/cs	Vinyl Chloride Polymers and Copolymers, Polyvinyl Acetate, Synthetic Rubbers, Nitrocellulose, Cellulose, Acetobutyrate, Polymethyl Methacrylate.	Non-Migratory, Permanent
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(*continued from page 521*)

The erosion rate of the laminates by the oxyacetylene torch test is shown in *Figure 10*. Note that the silicone and phenolic (H-9565) laminates gave the best resistance in this test.

A weight loss study at 250°C was conducted on several resin films (1) for a better understanding of their resistance to oxidation and thermal degradation. Films about 10 mils thick were prepared and aged in air and in nitrogen and the weight losses recorded at various aging times. *Figure 11* shows the loss in air, and *Figure 12* shows the weight loss in nitrogen. The phenolic resin used in the weight loss tests was second only to the more expensive silicon resin.

Conclusions

The use of the specially-designed phenolic resin and the choice of a postbaking cycle produces glass- reinforced laminates which have excellent physical and electrical properties and will retain a substantial proportion of these characteristics under high temperature conditions.

The high temperature siliceous reinforcements show better erosion resistance than does glass, but, in flexural strength, glass is superior. The high temperature phenolic resin laminates used in these tests compare favorably with the expensive silicone laminates in weight loss and erosion tests but far excel in flexural strength.

On the thermal and oxidative degradation studies of the resins in film form, the phenolic resin again compares favorably with silicone.

For high temperature applications, a specially-tailored phenolic resin, properly postbaked, is an excellent choice of binder for any of the siliceous fillers, both from a cost and physical property standpoint.

Acknowledgements

The author wishes to acknowledge the help of Dr. D. E. Baldwin and R. H. Lunn for the discussions and criticisms during the planning and execution of the experimental work.

The preparation of the charts and graphs by R. W. Russell is appreciated.

Literature References

(1) Westinghouse Research Laboratories, E. J. Traynor and L. D. Hofmeister *Research Report No. 10-0402-4-R3*

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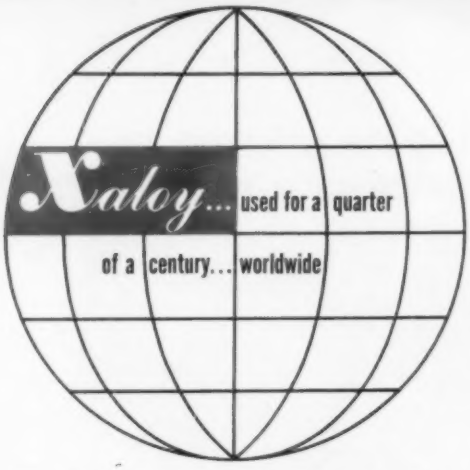

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POLYMER SCIENCE

Dynamic Mechanical Properties of High Polymers

Dynamic mechanical tests measure the response of a material to stresses which vary with time. Generally the deformation of the test specimen is determined as a function of an applied stress which varies sinusoidally. From such measurements it is possible to calculate an elastic modulus (shear or tensile depending upon the experimental apparatus) and the mechanical damping or energy dissipation. Objects which are nearly perfectly elastic such as a rubber band or a good spring convert mechanical work into potential energy when they are deformed. This potential energy may then be converted back into mechanical energy when the applied forces are removed. No energy is lost as heat, so the mechanical damping is zero for a perfectly elastic material. On the other hand, certain materials such as liquids convert nearly all the energy used to deform them into heat; none of the energy is stored as in a stretched spring. High polymeric materials have some of the properties of both elastic materials and viscous liquids; in other words, they are viscoelastic substances. When work is done in deforming such a substance, part of the energy is stored and part is converted into heat which may manifest itself as mechanical damping.

Dynamic mechanical measurements are of interest from both the practical and the theoretical standpoints. The modulus tells one the stiffness of the material. A modulus of 10^7 dynes/cm^2 (145 pounds/sq. inch) indicates a rubbery material while a modulus of 10^{10} dynes/cm^2 (145,000 pounds/sq. inch) is a typical value for a rigid plastic. A material with a very high damping is generally tough, but it may heat up under repeated cyclic deformations. A material with low damping may be brittle, but it will not tend to heat up when subjected to repeated deformations.

The theoretical interest in dynamic mechanical tests results from their great sensitivity to many structural features of high polymers. The

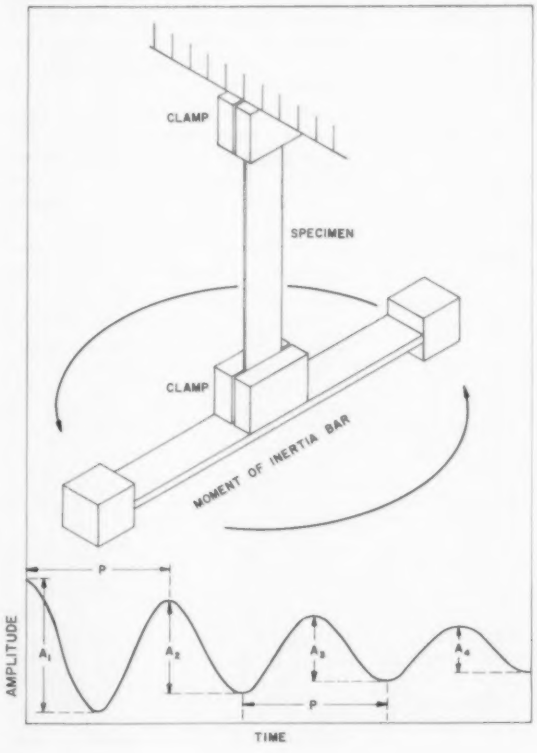


Figure 1. Schematic diagram of a torsion pendulum for measuring dynamic mechanical properties. A typical damped oscillation curve is illustrated at bottom of figure.

mechanical properties are strongly dependent upon glass transitions, melting of crystallites, crosslinking, state of aggregation, number of phases present in the material, and many other details of the inter- and intramolecular structure of polymer chains.

To characterize a material, the modulus and damping should be determined over a wide range of both temperature and frequency of deformation. However, much information may be obtained in a short time by varying the temperature and keeping the frequency relatively constant.

Apparatus

Many types of instruments have been used to measure dynamic mechanical properties. (6, 13, 18, 30) The simplest apparatus is a torsion pendulum such as shown schematically in *Figure 1*. (25, 26, 32, 34) One end of the specimen is rigidly clamped while the other end is clamped to a freely supported bar or disk of known moment of inertia. When the polar moment of inertia member and the specimen are given a twist and released, the system will oscillate with a period P, and the amplitude of the oscillations will decrease with time. The shear modulus G is related to the period of the oscillations while the mechanical damping or logarithmic decrement Δ is determined by the rate of decrease of the amplitude of the angle of twist. As long as the damping is not very high, the shear modulus of a specimen of rectangular cross section is given by:

$$G = \frac{5.588 \times 10^{-4}\, LI}{CD^3\, \mu P^2}$$

G = shear modulus in pounds per square inch.

L = length of specimen between clamps in inches.

C = width of specimen in inches.

D = thickness of specimen in inches.

I = moment of inertia in g—cm^2.

P = period of the oscillations in seconds.

μ = a shape factor whose value is given in *Table 1*.

The shear modulus for specimens of a circular cross section is given by:

$$G = \frac{3.59 \times 10^{-4}\, LI}{R^4\, P^2}$$

where R is the radius in inches.

The logarithmic decrement Δ is given by the logarithm (to the base e) of the ratio of the amplitudes of two successive oscillations.

$$\Delta = \ln\frac{A_1}{A_2} = \ln\frac{A_2}{A_3} = \ln\frac{A_3}{A_4} \ldots$$

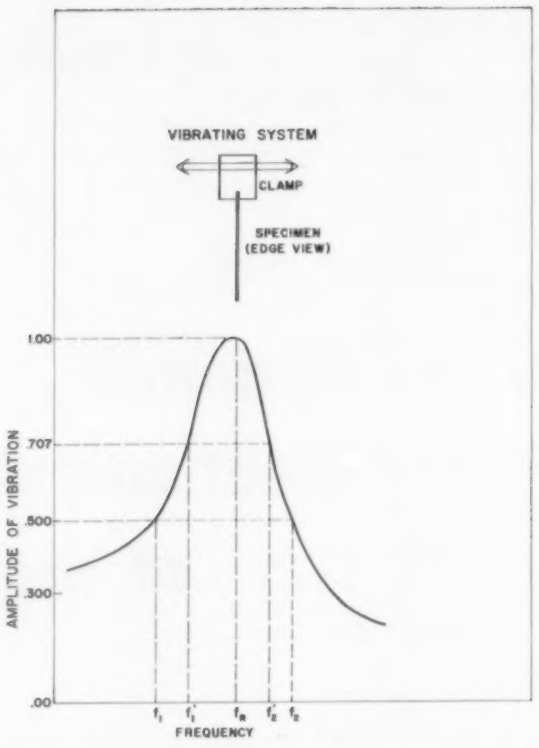


Figure 2. Typical amplitude-frequency curve obtained with a vibrating reed apparatus.

where A_1 is the amplitude of the first oscillation, A_2 the amplitude of the second oscillation, and so forth as shown at the bottom of *Figure 1*. The above equations are accurate only if there is essentially no tensile load on the specimen. For this reason the moment of inertia member should be very light, or its weight should be counterbalanced.

Another common type of apparatus is the vibrating reed. (1, 15, 31, 35) In this apparatus, schematically shown in *Figure 2*, a plastic strip is clamped at one end and forced to vibrate transversely. As the frequency of the vibrations is changed, the amplitude of the free end of the specimen will go through a maximum at its natural resonance frequency as illustrated in *Figure 2*. Young's modulus E is given by:

$$E = 38.24P\frac{L^4}{D^2}f_r^2$$

E = Young's modulus in dynes/cm^2. Answer may be converted to pounds per square inch by multiplying by 1.45×10^{-4}.

ρ = density of the specimen in g./cc.

L = free length of specimen in centimeters.

D = thickness of specimen in centimeters.

f_r = resonance frequency in cycles per second.

A damping may be calculated from the half width of the resonance peak or from the half power width of the resonance peak.

$$\text{Half width} = \frac{f_2 - f_1}{f_r}$$

$$\text{Half power width} = \frac{f_2' - f_1'}{f_r}$$

where, as shown in *Figure 2*, f_1 and f_2 are the frequencies at which the amplitude is one-half the maximum amplitude, and f_1' and f_2' are the frequencies at which the amplitude is 0.707 of the maximum amplitude.

Table 1

Ratio of Specimen Width to Thickness C/D	Shape Factor μ
1.00	2.249
1.20	2.658
1.60	3.250
2.00	3.659
2.50	3.990
3.00	4.213
4.00	4.493
5.00	4.662
7.00	4.853
10.00	4.997
20.00	5.165
50.00	5.266
100.00	5.300

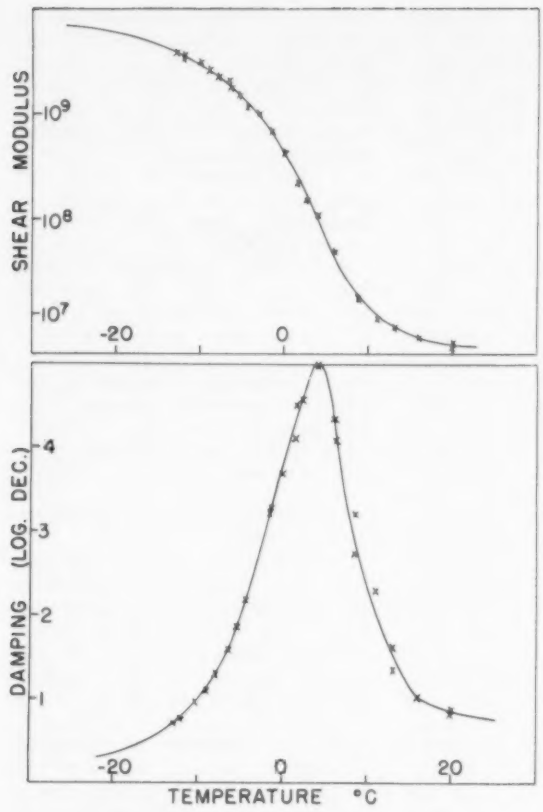


Figure 3. Dynamic mechanical properties of a styrene-butadiene copolymer as a function of temperature. Copolymer contains 60% styrene.

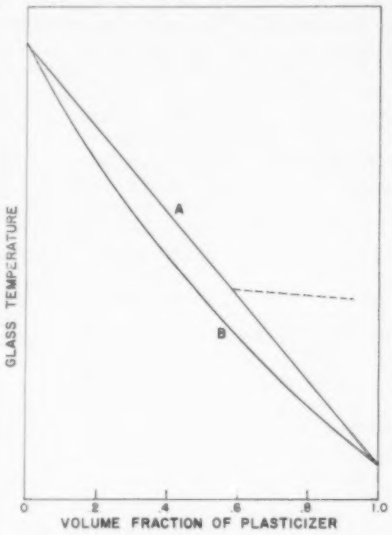


Figure 4. Variation of glass transition temperature or temperature of maximum damping as a function of plasticizer (or comonomer) concentration. Dotted line represents the behavior if incompatibility occurs.

A third type of apparatus is the rotating beam apparatus. (16, 17, 20, 22) In this apparatus a rod of circular cross section is clamped at one end and rotated as in the chuck of a lathe. A force is applied to the free end of the rod to bend it away from the center of rotation. Young's modulus is calculated from the deflection of the rod and the applied transverse force. The combination of the rotation and transverse force causes the end of the specimen to deflect in a direction different from the direction of the applied force. The mechanical damping is measured by the tangent of the angle between the applied force and the direction of deflection from the equilibrium position with no stress. For this apparatus with a weight on the end of a horizontal rod to deflect it:

$$E = \frac{416.3\ WL^3}{YR^4}$$

$$\text{Damping} = \tan \delta$$

where

E = Young's modulus in dynes/cm².
L = length of the horizontal rod in cm.
R = radius of the rod in cm.
Y = deflection of free end of rod in centimeters by a weight of W grams hanging from its end.
δ = angle between applied transverse force and the observed direction of deflection as seen looking along the axis of rotation.

The types of instruments discussed above illustrate measurements made with: (1) free vibrations, (2) forced vibrations with resonance, (3) forced vibrations without resonance. Many examples of each type may be found in the literature. In general the instruments making use of forced vibrations without resonance are the most desirable since a range of frequencies may be studied without changing the specimen, or the frequency may be held constant as the temperature is varied. However, these instruments are generally complex, the calculations are involved, and they may be limited in the range of modulus or damping that can be covered. An example of a very versatile instrument of this type which has been used by a number of investigators is the Fitzgerald apparatus. (11, 21)

Different instruments give mechanical damping data in different forms. It is often desirable to compare data obtained by different techniques, so some method of interrelating the various damping expressions is needed. In order to effect this interrelation, dynamic mechanical properties are generally expressed in terms of complex moduli such as:

$$G^* = G' + iG''$$

where G^* is the complex modulus, G' is the real part of the modulus, G'' is the imaginary part of the modulus (a damping or heat dissipation term), and i is the square root of -1. A damping expression called the dissipation factor is defined as G''/G'. Various other methods of expressing damping are given in terms of G''/G' (or E''/E'). Some of the more important interrelationships are:

$$G''/G' = \frac{4\pi\Delta}{4\pi^2 - \Delta^2} \text{ or } \Delta \doteq \pi \frac{G''}{G'}$$

$$\frac{f_2 - f_1}{f_r} = \sqrt{3}\ E''/E'$$

$$\frac{f_2' - f_1'}{f_r} = E''/E'$$

$$\tan \delta = E''/E' = Q^{-1}$$

Theory

There is no good molecular theory of the dynamic mechanical properties of high polymers. The kinetic theory of rubber elasticity (12) enables one to estimate the dynamic modulus of crosslinked polymers or rubbers at temperatures well above the glass temperature as long as the frequency is not too high. The effects of chemical structure, molecular weight, and chain architecture have for the most part been studied empirically.

Phenomenological theories of mechanical properties of high polymers are fairly advanced on the other hand. By making use of the concept of relaxation times or by using models

made up of springs and dashpots, it is possible to explain the mechanical behavior of polymers. The Ferry reduction principle (9, 10) or the Williams-Landel-Ferry method (37) of treating dynamic mechanical data are important and useful advances in the theory, but they will not be discussed in detail as they do not explicitly deal with structural features.

Relation of Dynamic Properties to Structure of Polymers

A. Segmental Mobility and Glass Temperatures

Most of the data to be discussed were obtained with a torsion pendulum apparatus, so the dynamic properties are expressed as the shear modulus G and the logarithmic decrement Δ. However, very similar results would have been obtained using another type of instrument. Temperature, rather than frequency has been chosen as the important variable. The frequency was not held constant but varied with temperature; the frequency varied around one cycle per second.

Typical results for an amorphous polymer are shown in *Figure 3*. At low temperatures the material is rigid with a high modulus. On raising the temperature the modulus gradually decreases until the glass transition region (3, 8) is reached where the modulus drastically decreases by a factor of about a thousand. At higher temperatures, where the material is rubbery in nature, the modulus again decreases at a much slower rate. The great change in the modulus which occurs near the glass temperature at low frequencies is due to the onset of chain segment mobility. At low temperatures the chain segments are "frozen in" and cannot readily respond to an applied stress. In the high temperature rubbery region the segments have great mobility and become free to move when a stress is applied; therefore, the modulus is low. In the transition region only part of the chain segments are free to move in the course of one second; a larger number of segments will have time to move in say ten seconds. Because of this time dependence of the number of mobile segments, the glass transition temperature region will shift with the frequency of the oscillations. In general the break in the modulus curve (or the peak in the damping curve) will shift roughly 7°C. for each factor-of-ten change in frequency. An increase in frequency corresponds to an increase in temperature in shifting the transition region.

The logarithmic decrement curve in *Figure 3* shows that the damping goes through a large maximum in the glass transition region. When the molecular segments are frozen-in or when they are free to move as in a rubber, the material acts as an elastic body so the damping is low. However, when only part of the segments are free to move in a given length of time, the damping becomes large, and the material has a "dead" or leathery feel when deformed. The reason for high damping in the transition region is easily visualized: In the frozen-in state each molecular segment acts as though it were a very stiff spring while in the rubbery state a mobile segment acts like a very weak spring. When a stress is first applied, the segments have not had time to move, so the energy is stored as potential energy in stretching the stiff springs. An instant later some of the segments become free to move under the applied stress, but the remaining frozen-in segments (stiff springs) prevent them from stretching much more. For a given deformation a weak spring can store much less potential energy than a stiff spring. Therefore, the weak springs (mobile segments) must give up most of their energy as heat when they change from stiff springs to weak springs. This heat generation is the source of the mechanical damping. When the spring elements remain essentially all stiff or all weak, the damping is low. When many of the stiff springs change to weak springs in a time interval comparable to the time to make one oscillation, the damping is high. Another manifestation of the loosening of the structure with time in the transition region is the deformation lagging behind the stress. The phase angle between the stress and the strain is analogous to the loss angle in dielectric measurements.

When discussing glass transitions as measured by dynamic mechanical tests, it is convenient to define the glass temperature as that temperature at which the damping is a maximum. This is generally a few degrees higher than a glass temperature measured from volume-temperature measurements.

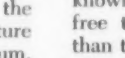
The glass transition region of a polymer may be shifted by adding plasticizers or by forming copolymers. Since the behavior of plasticizers and comonomers is so similar in changing the properties of a pure homopolymer, they shall be discussed together. For a material to act as a plasticizer, it must be soluble in the polymer. The plasticizer must also have a low glass temperature of its own. In many systems the lowering of the glass temperature is nearly a linear function of the volume fraction of plasticizer in the polymer as illustrated by curve A in *Figure 4*. In other systems a small amount of plasticizer is relatively more efficient than a large amount, so a curve such as B in *Figure 4* is followed. Similar curves are obtained for copolymers if volume fraction of plasticizer is replaced by volume fraction of comonomer. More complex relations than curve A of *Figure 4* have been proposed to express the glass temperature as a function of composition. These have been reviewed by Wood. (39)

In addition to shifting the glass temperature, plasticizers generally broaden the transition region so that it covers a wider temperature range than the pure homopolymer. This effect is especially noticeable if the plasticizer reaches a saturation limit; additional plasticizer then has little effect on the glass temperature as indicated by the dotted line in *Figure 4*.

B. Secondary Transitions and Damping Peaks

In addition to the damping peak due to the mechanism discussed in the previous section, a polymer may show other damping peaks. These secondary peaks may be due to: (1) Side Groups; (2) Two phase systems or aggregates; (3) Morphological and other effects such as crystal size in crystalline polymers or intergrain slippage.

An example of a material with a side group is polymethyl methacrylate whose dynamic properties are shown in *Figure 5*. The large damping peak at 130°C. represents the glass temperature where whole segments of the chain molecules become free to move. The broad peak centered around 40°C. has been shown to be due to



motion of the —C(=O)—O—CH_3 side group. (5) Many other examples are known in which a side group becomes free to move at lower temperatures than the backbone chain. (14, 24, 36) The methyl group has been found to produce a damping peak around −260°C. in polypropylene. (24) Alkyl groups containing three or more methylene units in a row give rise to a peak near −110°C. The cyclohexyl unit as a side group produces a damping peak near −30°C. (14) Polymers containing hydroxyl groups or water often show a peak at low temperatures.

Since most polymers are quite insoluble in one another, a mixture of two polymers generally results in a two phase system. Such systems show two damping peaks—the peaks correspond to the glass transitions of the two pure polymers (4). *Figure 6* shows the behavior of a mixture of polystyrene and a rubbery copolymer of butadiene and styrene. The peak at −30°C. is the transition temperature

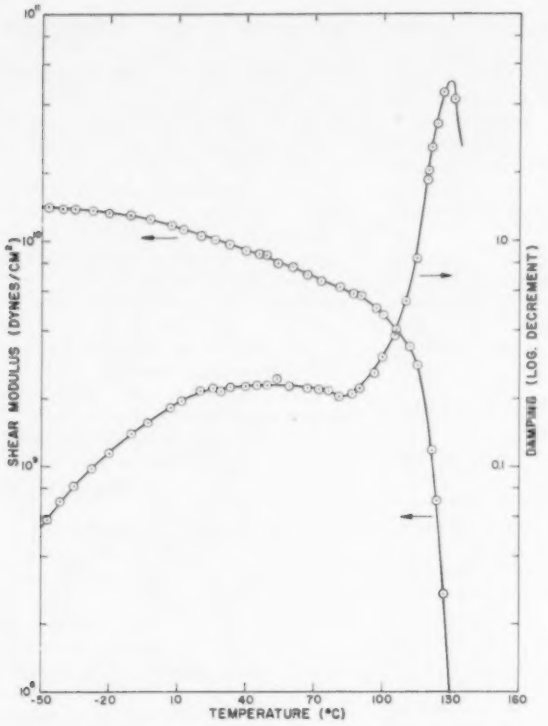


Figure 5. Dynamic mechanical properties of polymethyl methacrylate.

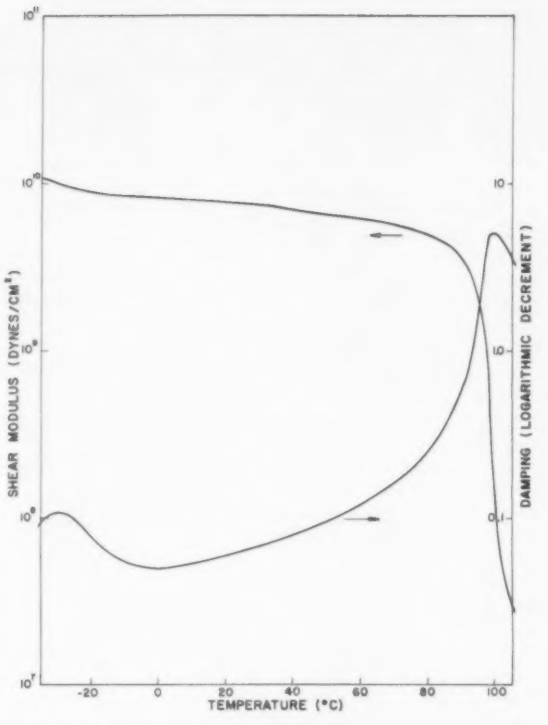


Figure 6. Dynamic mechanical properties of a mixture of polystyrene and a smaller amount of a styrene-butadiene copolymer.

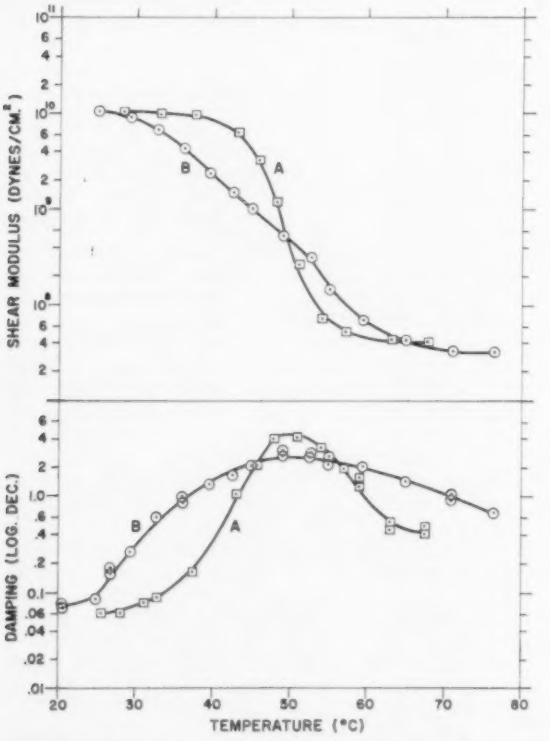


Figure 7. Dynamic mechanical properties of vinyl chloride-methyl acrylate copolymers: A. Homogeneous; B. Heterogeneous. Reprinted from J. Amer. Chem. Soc. **75,** 1435 (1953). Reference 27.

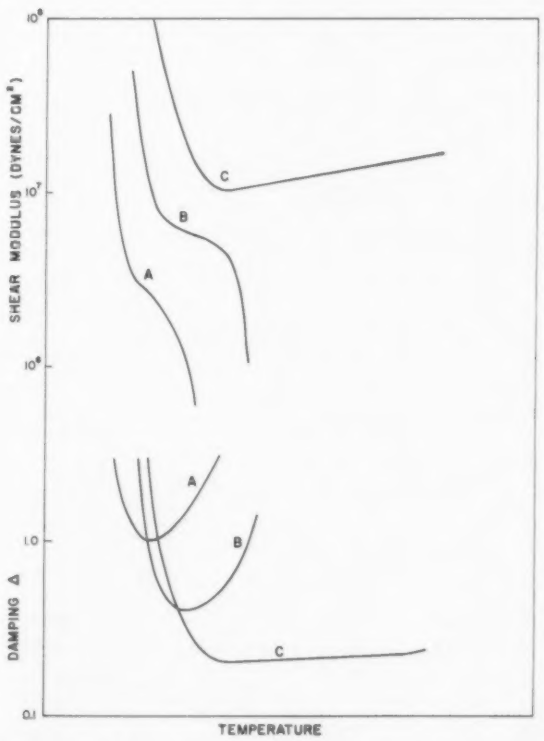


Figure 8. Schematic representation of the dynamic mechanical properties of amorphous polymers above the temperature of maximum damping. A. Low molecular weight polymer. B. High molecular weight polymer. C. Crosslinked polymer.

of the copolymer while the peak at 100°C. is the glass transition temperature of the polystyrene phase. As more copolymer is added to the mixture, the peak remains at about −30°C., but its height increases while the height of the polystyrene peak decreases.

Not all polymers are insoluble in one another. Mixtures in which the two components are miscible in one another give curves similar to those shown in *Figure 3* except for a broader transition range. (27) The damping peak occurs at a temperature between the damping peaks of the pure components.

Graft and block polymers often behave as two phase systems and show two damping peaks. (2) Unless the two types of chains are very similar in solubility behavior, they tend to form molecular aggregates even though the chain segments are attached to each other by chemical bonds.

Inert, insoluble, rigid fillers increase the modulus of a material and may slightly raise the temperature of the damping peak. However, such fillers generally do not introduce a damping peak of their own. They may either raise or lower the damping depending upon such factors as the type of filler and the adhesion between the two phases. (29)

In most copolymers not all the molecules have the same chemical composition. Interchain chemical heterogeneity is introduced because one monomer is relatively more reactive than the other so that the composition of the polymer changes during the course of the polymerization. *Figure 7* shows that a heterogeneous copolymer has a broader transition region than a homogeneous one in which all the molecules have the same chemical composition. (27)

Secondary damping peaks may arise from various other causes such as the melting of crystallites of different sizes. This type of transition will be discussed in more detail in the section on crystalline polymers.

C. *Effects Due to Molecular Weight and Crosslinking*

Molecular weight in general does not affect the dynamic mechanical properties at temperatures below the glass temperature. However, above the glass temperature the properties are very sensitive to molecular weight and molecular weight distribution. Curves A and B of *Figure 8* illustrate the type of results to be expected above the glass temperature. Curve A is for a low molecular weight polymer while curve B is for a higher molecular weight. The rapid decrease in both the modulus and damping as the temperature is raised is due to the last part of the glass transition region, most of which occurs at temperatures below those shown in the graph. At higher temperatures the modulus takes a second drop and the damping increases with temperature; the phenomena are due to the more rapid disappearance of chain entanglements which act as temporary crosslinks and the onset of viscous flow. The lower the molecular weight the lower the temperature at which these effects become prominent. Broad distributions in molecular weight give much broader damping minima than fractions. (23)

Curve C of *Figure 8* shows the expected behavior for a crosslinked rubber or polymer above the glass temperature. The crosslinks prevent viscous flow from taking place, so the second drop in the modulus does not take place. The modulus may even increase gradually with temperature as predicted by the kinetic theory of rubber elasticity. Because the effects of chain slippage and viscous flow are minimized by the crosslinks, the damping remains low.

As the extent of crosslinking increases in a material, the damping peak shifts to higher temperatures, and the transition region broadens. At the same time the modulus above the glass temperature increases. At extremely high degrees of crosslinking the transition region becomes so broad and occurs at such high temperatures that the material may decompose before any sign of a damping peak is observed. These effects are shown in *Figure 9* for a phenol-formaldehyde material at different degrees of curing. (7)

D. *Crystalline Polymers*

Crystalline polymers show much more complicated dynamic mechanical behavior than amorphous polymers. Crystalline polymers generally have a main glass transition and one or

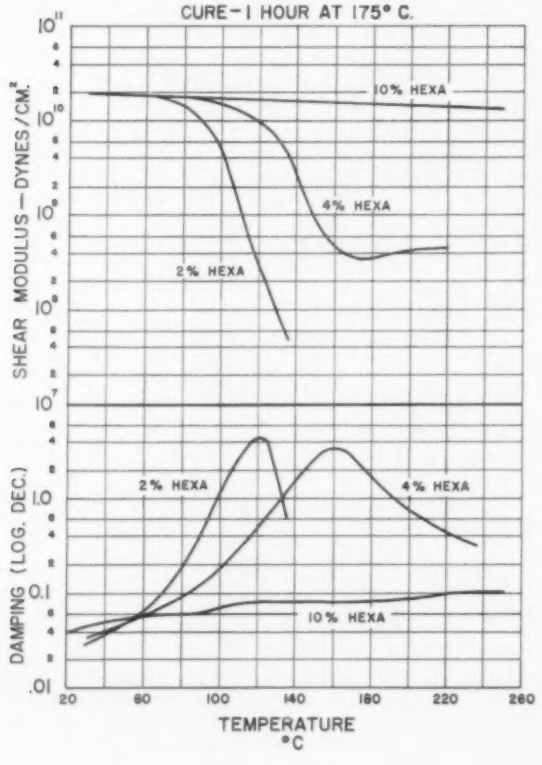


Figure 9. Dynamic properties of a phenol-formaldehyde novolac crosslinked with various amounts of hexamethylenetetramine by heating for one hour at 175°C. Reprinted from Ind. Eng. Chem. **48**, 76 (1956). Reference 7.

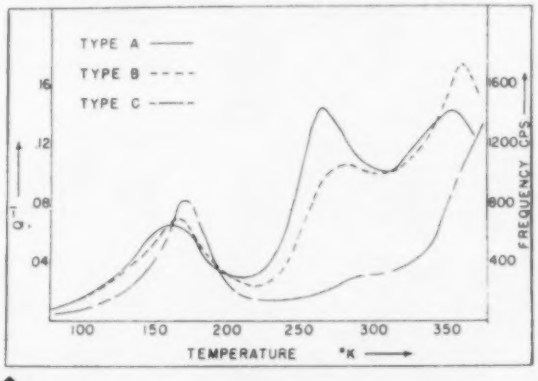


Figure 10. Dependence of damping as a function of temperature on branching for polyethylene. Type A: 3.2 CH_3's/100 CH_2; Type B: 1.6 CH_3's/100 CH_2; Type C: <0.1 CH_3's/100 CH_2. Data of Kline, Sauer and Woodward, J. Polymer Sci. **22**, 455 (1956).

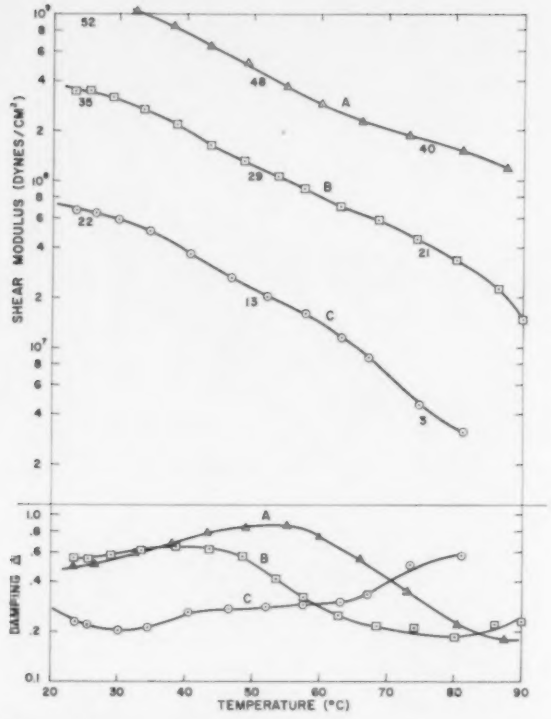


Figure 11. Dynamic mechanical properties of three polyethylene type polymers with different degrees of crystallinity. Numbers on curves refer to degree of crystallinity at 25°C., 50°C., and 75°C.

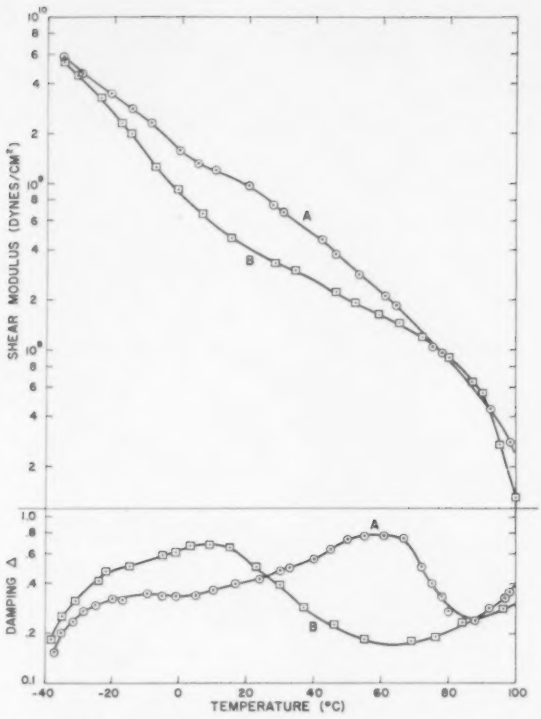


Figure 12. Dynamic mechanical properties of a polyethylene polymer. A. Slowly cooled from melt to 20°C. B. Quenched from melt at 150°C. into ice water.

more secondary transitions, and in addition they show the effects due to the melting of the crystallites and transitions within the crystalline phase. (33, 38, 40) Polyethylene is a typical semicrystalline polymer. *Figure 10* shows data for three polyethylenes of different degrees of branching. (19) There are damping peaks around 60°C., −25°C., and −110°C. The peak near 60°C. is related to the crystalline phase and will be discussed below. The transition near −25°C. is related to the amorphous phase containing the branch points or other units which break up the uniformity of the polyethylene chain. The transition near −110°C is due to amorphous CH_2 sequences of three or four carbons or longer.

Even above the highest glass transition the modulus may remain high because the crystallites not only act as crosslinks to the amorphous phase, but the rigid crystallites may also bear part of the stress. The temperature dependence of the elastic modulus may be much greater than for a chemically crosslinked rubbery material. This is because of the change in degree of crystallinity with temperature; the small and imperfect crystallites melt at a much lower temperature than large or more nearly perfect crystallites. Thus the temperature dependence of the modulus may be used to estimate the distribution of crystallite sizes. *Figure 11* shows the temperature dependence of the modulus of three polyethylene materials of different degrees of crystallinity. The higher the crystallinity, the higher the modulus.

The melting point of many crystalline polymers can be measured by dynamic mechanical measurements. As long as there are enough crystallites to bind the molecules together, the damping will be relatively small, and the modulus will be well above 10^8 dynes per square centimeter. At the final melting point the modulus will drastically drop, and the damping will increase. (28)

Crystalline polymers are more sensitive to heat treatments than are amorphous polymers. By various heat treatments it is possible to not only change the degree of crystallinity, but also the size of the crystallites and the morphology of the material. This is illustrated in *Figure 12* for a polyethylene material quenched in ice water from the melt in one case and slowly cooled through the melting point in the other case. Part of the striking differences are due to the slowly cooled sample being more crystalline than the quenched sample, but most of the difference is due to the smaller crystallites in the quenched material. This difference in crystallite size manifests itself as a large shift in the high temperature damping peak.

The effect of crystallite size also is shown by the damping curves in *Figure 11*. As the "branching" or disrupting units increase in going from curves A to C the high temperature peak shifts from 55°C. to 40°C. for material B and to near 0°C. for material C. As more branch points or foreign units break up the polyethylene chains into shorter sequences of CH_2 groups, the length of the crystallites must also decrease. The factors which may break up the uniformity of the backbone of a chain are branch points, comonomer units, or the degree of isotacticity. These factors decrease both the degree of crystallinity and the size (or perfection) of the crystallites.

Summary

An attempt has been made to point out the importance of dynamic mechanical measurements from both the theoretical and the practical viewpoints. A great variety of instruments can be employed in obtaining data either as a function of frequency or temperature. Dynamic mechanical measurements are sensitive indicators of various glass transitions and the

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factors which change these transitions. These techniques can also be used to study the effect of crystallinity and the size of crystallites as well as many other factors which affect the mechanical properties of high polymers.

Acknowledgment

The author thanks the American Chemical Society for permission to reprint *Figures 7 and 9* and the Interscience Publishers, Inc. for permission to reprint *Figure 10*.

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Literature References

1. Ballou, J. W. and Smith, J. C., *J. Appl. Phys. 20*, 493 (1949).
2. Blanchette, J. A. and Nielsen, L. E., *J. Polymer Sci. 20*, 317 (1956).
3. Boyer, R. F. and Spencer, R. S., *J. Appl. Phys. 15*, 398 (1944), *16*, 594 (1945) and *17*, 398 (1946).
4. Buchdahl, R. and Nielsen, L. E., *J. Appl. Physics. 21*, 482 (1950), *J. Polymer Sci. 15*, 1 (1955).
5. Deutsch, K., Hoff, E. A. W. and Reddish, W., *J. Polymer Sci. 13*, 565 (1954).
6. Dillon, J. H. and Gehman, S. D., *India Rubber World 115*, 61 and 217 (1946).
7. Drumm, M. F., Dodge, C.W.H. and Nielsen, L. E., *Ind. Eng. Chem. 48*, 76 (1956).
8. Eirich, F. R., *Rheology, Vol. 2*, Chapter By R. Buchdahl, p. 145. Academic Press, Inc., New York, (1958).
9. Ferry, J. D., J. *Amer. Chem. Soc., 72*, 3746 (1950).
10. Ferry, J. D., Fitzgerald, E. R., Grandine, L. D. Jr., and Williams, M. L., *Ind. Eng. Chem. 44*, 703 (1952).
11. Fitzgerald, E. R. and Ferry, J. D., *J. Colloid Sci. 8*, 1 (1953).
12. Flory, P. J., *Principles of Polymer Chemistry*, Cornell University Press, Ithaca, N. Y., (1953).
13. Gehman, S. D., *Rubber Chemistry and Tech. 30*, 1202 (1957).
14. Hoff, E. A. W., Robinson, D. W. and Wilbourn, A. H., *J. Polymer Sci. 18*, 161 (1955).
15. Horio, M. and Onogi, S., *J. Appl. Phys. 22*, 977 (1951).
16. Kimball, A. L., *General Electric Rev. 27*, 244 (1924).
17. Kimball, A. L. and Lovell, D. E., *Trans. A.S.M.E. 48*, 479 (1926).
18. Kline, D. E., *J. Polymer Sci. 22*, 449 (1956).
19. Kline, D. E., Sauer, J. A. and Woodward, A. E., *J. Polymer Sci. 22*, 455 (1956).
20. Lazan, B. J., *Trans. A.S.M.E. 65*, 87 (1943).
21. Marvin, R. S., Fitzgerald, E. R. and Ferry, J. D., *J. Appl. Phys. 21*, 197 (1950).
22. Maxwell, B., *J. Polymer Sci. 20*, 551 (1956).
23. Merz, E. H., Isaksen, R. A. and Cox, W. P., Submitted for Publication.
24. Muus, L. T., McCrum, N. G. and McGrew, F. C., *Soc. Plastics Eng. J. 15*, 368 (1959).
25. Nielsen, L. E., *A.S.T.M. Bull. #165*, 48 (1950).
26. Nielsen, L. E., *Rev. Sci. Inst. 22*, 690 (1951).
27. Nielsen, L. E., *J. Amer. Chem. Soc. 75*, 1435 (1953).
28. Nielsen, L. E., *J. Appl. Phys. 25*, 1209 (1954).
29. Nielsen, L. E., Wall, R. A. and Richmond, P. G., *Soc. Plastics Eng. J. 11* #7, 22 (1955).
30. Nolle, A. W., *J. Appl. Phys. 19*, 753 (1948).
31. Robinson, D., *J. Sci. Inst. 32*, 2 (1955).
32. Schmieder, K. and Wolf, K., Kolloid Z. *127*, 65 (1952).
33. Schmieder, K. and Wolf, K., Kolloid Z. *134*, 149 (1953).
34. Sinnott, K. M., *J. Appl. Phys. 29*, 1433 (1958).
35. Strella, S., *A.S.T.M. Bull. #214*, 47 (1956).
36. Wilbourn, A. H., *Trans. Faraday Soc. 54*, 717 (1958).
37. Williams, M. L., Landel, R. F., and Ferry, J. D., *J. Amer. Chem. Soc. 77*, 3701 (1955).
38. Wolf, K. and Schmieder, K., International Symposium on Macromolecular Chemistry, Milan, 1955.
39. Wood, L. A., *J. Polymer Sci. 28*, 319 (1958).
40. Woodward, A. E. and Sauer, J. A., *Fortschr. Hochpolym. Forsch. (Advances in Polymer Science), 1*, 114 (1958).

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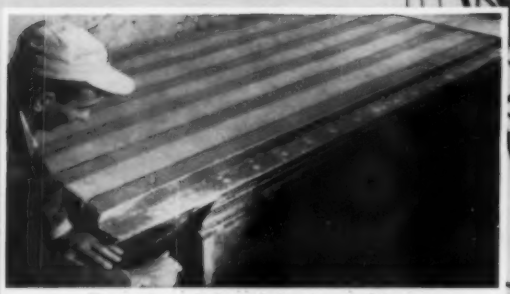

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SPE JOURNAL

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Color Stability of Vinyl Compounds Pigmented With Iron Oxides

Arthur K. Woernle
C. K. Williams & Co.

Elevated temperature tests of iron oxide-vinyl plastic compositions show that excellent color stability may be achieved with proper selection of commercial grade compounding ingredients. A variety of types and shades of iron oxides and a variety of stabilizers were successfully used. Variations of fillers, plasticizers and resins were also evaluated.

Iron oxide pigments comprise a class of colorants characterized by light fastness, heat stability, acid and alkali resistance and low cost. They are used in an unlimited number of applications to produce shades of yellow, orange, light red, red, maroon, brown and black, ranging from light pastels to deep tones. One of the applications is the coloring of vinyl compositions for various uses, a few examples of which are artificial leather, coatings, containers, electrical insulation, film and sheet stock, flooring, gaskets and seals, hose, household articles, toys, etc.

This article describes laboratory tests and results which show how vinyl compositions containing iron oxide color pigments may be readily stabilized. Numerous types and grades of commercial compounding ingredients were evaluated. The stabilizers employed in this investigation are not the only suitable grades, nor are they necessarily the best or tested at their optimum concentrations. An introductive rather than exhaustive study was made.

Test Procedure

The compositions were prepared by tumbling the dry ingredients for ten minutes, adding the preblended liquids and finally fluxing the composite for six minutes on a 6" by 12" mill having roll speeds of 31 and 24 rpm. and heated to 320°F. Stock temperatures of 335°F. were obtained. The milled stocks were compression molded at 340°F. and 1300-1600 psi pressure using a cycle of two minutes preheating, two minutes heating, and 5 minutes cooling to produce specimens with consistently smooth, uniform surfaces. They were cut into desired sizes, mounted on solvent-

Comment . . .

The formulations developed here and the principles described for imparting stability to polyvinyl plastics pigmented with iron oxide may be considered as an introduction to specific compounding for heat stability. In many cases more stability is shown than would be required. In other instances it may be desired (1) to obtain the same stability through the use of fewer ingredients or (2) to obtain additional stability and these might be done by using more general purpose plasticizer or epoxy plasticizer, polymeric plasticizer, additional quantities of calcium carbonate, combinations of stabilizers or greater quantities of a specific stabilizer. In no case are these studies being recommended as hard, fast rules but are being offered as guides to develop specific applications using iron oxide pigments. It is necessary that each compounder continue to follow the current practice of confirming the stability of his particular composition testing the same grades of ingredients as used in his production.

This article adapted from a paper presented at the 16th ANTEC—Chicago—January, 1960

washed aluminum foil and placed in a forced-draft oven having horizontal air movement. Tests were run primarily at three temperatures, 350°F., 365°F., 380°F., and in some instances at 400°F., and were checked with nine thermocouples which showed instantaneous variations up to + or — 1-½°F.

Samples were withdrawn from the oven at various intervals to evaluate degree of discoloration.

Nature of Discoloration

Oven heating of plastics pigmented with iron oxides produced no color change in the more stable compounds for the majority of their aging life. Near the end of this time sharp brown or black lines formed along an edge or point of the specimen and grew along the periphery and finally toward the center of the top surface. In 72% of the tests made, complete surface darkening occurred within 25% additional time elapse, based on the length of aging to produce initial peripheral discoloration. In 28% of the tests, complete surface darkening occurred after more than 25% additional time elapsed. After complete surface darkening, the discoloration gradually penetrated the sample until it was finally black throughout. This effect occurred for 98% of this work. Asbestos-filled stocks and one or two stabilizers showed only minor variations.

A Specialized Guide for the Compounding of Vinyl Plastics Containing Iron Oxide Pigments

Table 1. Comparing the Pigments. For Full Color Comparison, See Page 537

Effect of Oven Heating at 365°F.

Colorant	Minutes to Initial Discoloration	Color Evaluation at 75 Minutes	Color Evaluation at 180 Minutes
Light Calcined Pure Red Iron Oxide	195	No change from the unaged	No change from the unaged
Permanent Red 2B (1)	60 or less	Same as at 60′, slightly dark to the unaged	Slightly darker than at 75′
Permanent Red 2B (2)	30	Same as at 30′, slightly dark to the unaged	Slightly darker than at 75′
Pigment Scarlet (3)	75	Very slightly dark to the unaged	Darker than at 75′
Pigment Scarlet (4)	20	Slightly darker than at 20′	Dark brown
Toluidine Red	20	Darker than at 20′	Black
Derivative of Quinacridone	20	Same as at 20′, slightly dark to the unaged	Same as at 20′
Cadmium Mercury Red	210	No change from the unaged	No change from the unaged
Cadmium Red	150	No change from the unaged	Very slight darkening
Lithol Red	60 or less	Same as at 60′, slightly dark to the unaged	Black
BON Red	60	Same as at 60′, slightly brown to the unaged	Darker than at 60′
Indigo Toner	20	Same as at 20′, very slightly dark to the unaged	Slightly darker than at 60′
Chrome Yellow	60	Same as at 60′, slightly dark to the unaged	Darker than at 60′
Benzidine Yellow	75	Very slightly dark to the unaged	Dark greenish-yellow
Pure Chromium Oxide	120	No change from the unaged	Slight yellowing
Phthalocyanine Green	30	Same as at 30′, very slightly dark to the unaged	Same as at 30′
Pure Hydrated Chromium Oxide	20	Somewhat dark and yellow to the unaged	Yellower than at 75′

Numbers (1), (2), (3), and (4) refer to different suppliers of the pigments.

Comparing Various Colorants

The discoloration (p. 537) is in contrast to the effect of heat on many vinyl compositions. Unpigmented samples and samples colored with other pigments generally showed a gradual, uniform darkening over the entire surface. *Figure 1* shows comparisons in color between iron oxide and other colorants in a well stabilized composition heated at 365°F. *Table 1* verbally describes these relationships. Similar comparisons were obtained at 380°F.

The iron oxide composition is virtually unchanged. Those with Permanent red 2B, Pigment Scarlet, quinacridone derivative and the BON all darkened substantially as did the toluidine and lithol reds not generally used in vinyls. The cadmium and cadmium-mercury reds maintain color well. The chrome and benzidine yellows discolor badly. Chromium oxide is very stable. Hydrated chromium oxide shown on the bottom line is not quite so stable because of the breakdown of molecular water upon heating to convert to the anhydrous form. The satisfactory use of this depends upon total heat history or time-temperature combinations. The phthalocyanine green darkened slightly.

The overall evaluation demonstrates that this particular compound containing iron oxide was stabilized to have better heat stability than similar compositions containing the organic pigments and to have approximately the same heat stability as many of those containing the other inorganic colors tested. It is possible that color retention for the pigments which show darkening here may be improved by using stable formulations other than that used here.

EFFECTS OF OVEN EXPOSURE ON COLOR

(For quantitative data, see Table 1, page 536)

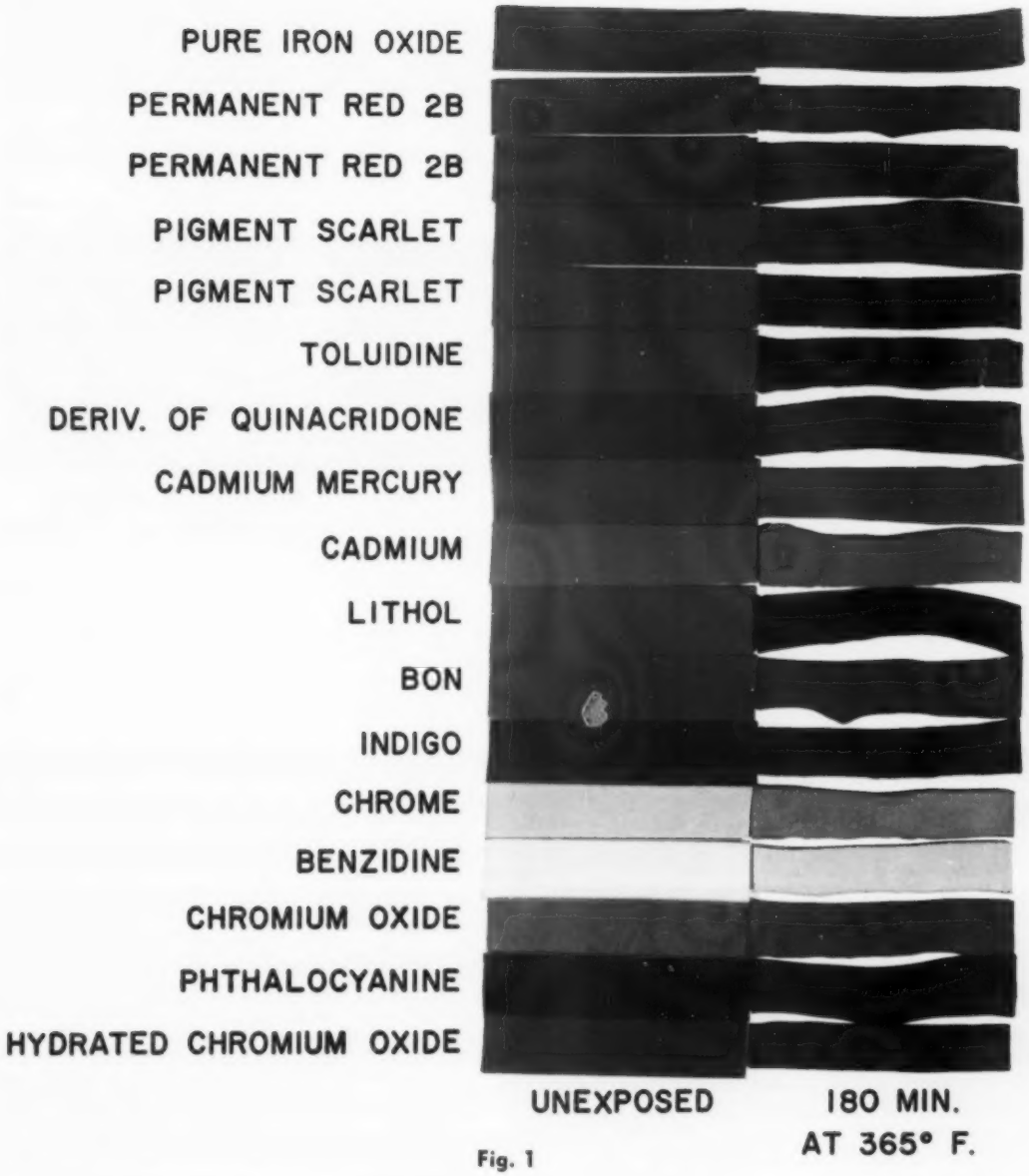


Fig. 1

Composition of test specimens:

Polyvinyl chloride-acetate	—100	Water ground $CaCO_3$	—50
DOP	—30	Stearic acid	—0.25
Epoxidized soybean oil	—5	Color pigment	—5
		Tetrabasic lead fumarate	—3

EFFECTS OF IRON OXIDE COLOR PIGMENTS ON STABILITY

MINUTES IN 380°F. OVEN

(For quantitative data, see Table 3, page 540)

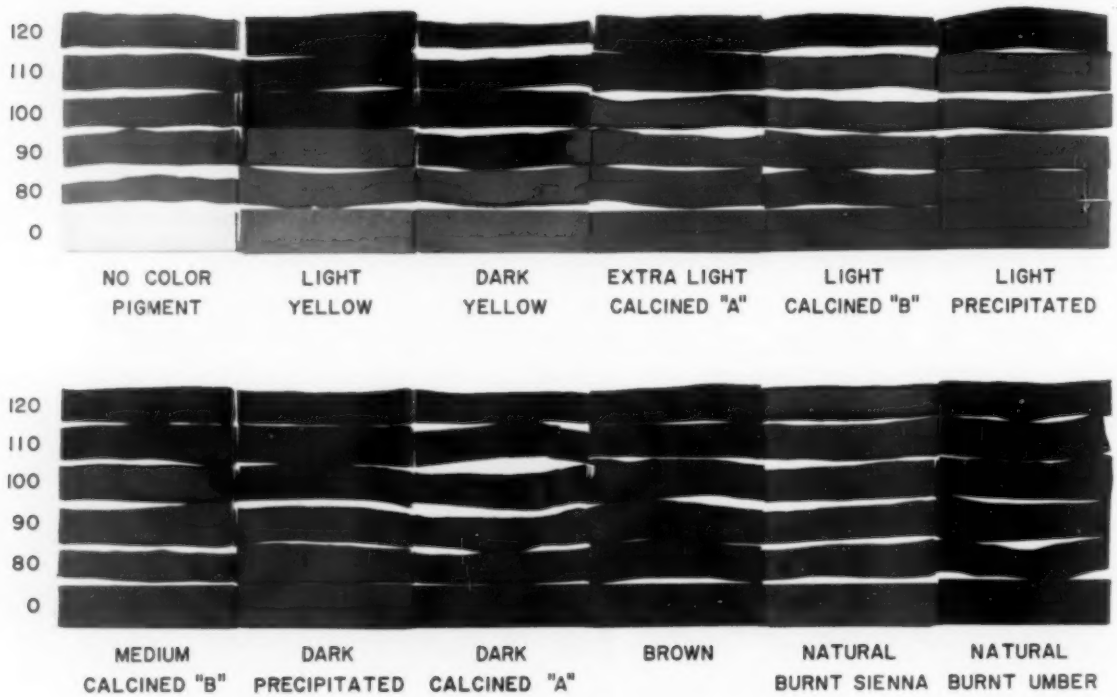


Fig. 2

EFFECTS OF CALCIUM CARBONATE AND CLAY ON STABILITY

MINUTES IN 380°F. OVEN

(For quantitative data, see Table 4, page 540)

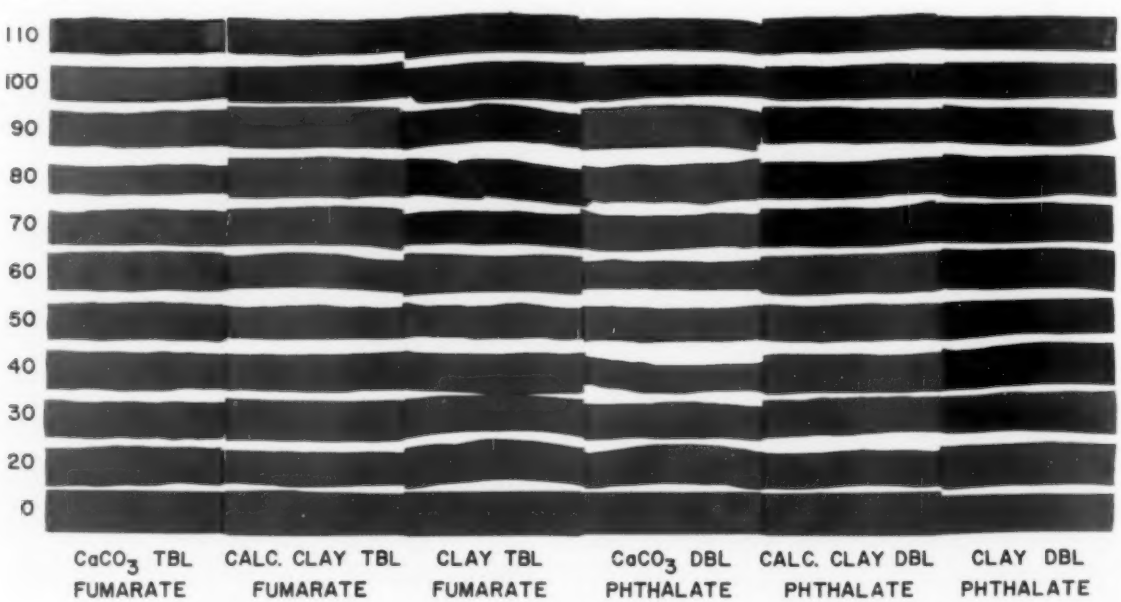


Fig. 3

Table 2. Building More Stable Compounds

Polyvinyl Chloride-Acetate	100
Stearic Acid	0.25
Light Calcined Pure Red Iron Oxide	5
All others	Shown

Mix No.	Additions		380°F. I	380°F. F	365°F. I	365°F. F	350°F. I	350°F. F
1	DOP	35	Would not mill (decomposed)					
2	DOP	35	<20	<20	20	30	40	60
	Water Ground $CaCO_3$	50						
3	DOP	30	30	40	50	60	90	100
	Epoxidized Soybean Oil	5						
4	DOP	30	40	55	65	85	115	130
	Epoxidized Soybean Oil	5						
	Water Ground $CaCO_3$	50						
5	DOP	30	65	80	110	140	185	230
	Epoxidized Soybean Oil	5						
	Water Ground $CaCO_3$	50						
	Ba-Cd (Phenate type) Liquid	3						
6	DOP	30	75	90	135	195	240	300
	Epoxidized Soybean Oil	5						
	Water Ground $CaCO_3$	50						
	Mercaptotin Liquid	2						
7	DOP	30	90	100	155	185	275	320
	Epoxidized Soybean Oil	5						
	Water Ground $CaCO_3$	50						
	Dibasic Lead Phthalate	2						
8	DOP	30	100	130	195	230	340	435
	Epoxidized Soybean Oil	5						
	Water Ground $CaCO_3$	50						
	Tetrabasic Lead Fumarate	3						
9	DOP	30	140	170	220	280	480	600
	Epoxidized Soybean Oil	5						
	Water Ground $CaCO_3$	50						
	Tetrabasic Lead Fumarate	5						
10	Polymeric Plasticizer	30	145	175	280	330	—	—
	Expoxidized Soybean Oil	5						
	Water Ground $CaCO_3$	50						
	Tetrabasic Lead Fumarate	3						

I = Initial time of discoloration (minutes).
F = Final time for complete top surface discoloration (minutes).

Guide for Compounding Vinyl Plastics

—Continued

Stepwise Increase of Heat Stability

An elementary compound containing 100 parts copolymer resin (97.5% PVC, 2.5% PVA), 35 parts DOP, 0.25 part stearic acid and 5 parts iron oxide was not stable enough to mill. Based on this four component system, compositions were developed in a stepwise manner to show gradually increasing degrees of stability, the best of which had greater stability than required for ordinary processes. *Table 2* and *Figure 4*, show that (a) adding only calcium carbonate (50phr) produced a 20 minute stability at 365°F. or (b) substituting only 5 phr epoxy plasticizer produced 50 minutes of stability.

Concurrently adding the filler and making the epoxy plasticizer substitution produced a composition that was stable for 65 minutes at 365°F. Subsequently adding 3 phr of a barium cadmium complex gave stability of 110 minutes. The alternate use of 2 phr mercaptotin liquid promoted stability of 135 minutes and use of 2 phr dibasic lead phthalate developed 155 minute stability. 3 phr tetrabasic lead fumarate promoted stability of 195 minutes and 5 parts of the same made the product maintain color up to 220 minutes. Use of a polymeric plasticizer in place of the general purpose plasticizer in the composition stabilized with 3 phr tetrabasic lead fumarate produced stability of 280 minutes at 365°F. Partial substitution of the polymeric plasticizer was proportionally effective.

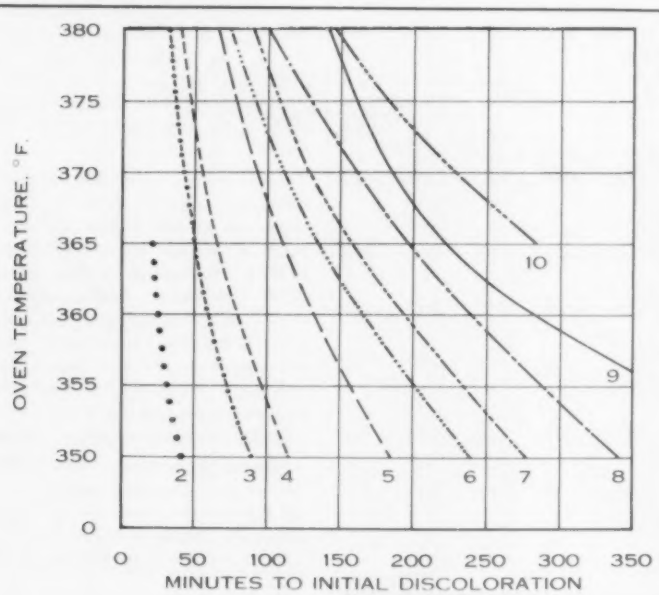


Figure 4. Color stability of vinyl plastics (mix numbers described in Table 2).

Color Stability vs. Temperature

One variable that was studied shows how stability changes with test temperature. Throughout this study oven aging at 350°F., 365°F., and 380°F. was employed. *Figure 4* shows the curves representing time—temperature plots of stability as indicated by initial peripheral discoloration. As anticipated, curved rather than straight lines were obtained. From the data it is seen that stability at 350°F. is about 3 times longer than stability at 380°F. for these compositions which contain iron oxide pigments. These curves are representative of many which could be prepared from the data presented herein and are shown as an example. Stability at 400°F. varies from 40% to 60% of the stability obtained at 380°F. *Table 2* describes mix numbers.

Table 3. Comparison of Grades of Iron Oxide. See Full Color Comparison on Page 538, Figure 2

Polyvinyl Chloride-Acetate	**100**
DOP	**30**
Epoxidized Soybean Oil	**5**
Stearic Acid	**0.25**
Color Pigment	**5**
Tetrabasic Lead Fumarate	**3**
Water Ground $CaCO_3$	**50**

Color Pigment	380°F. I	380°F. F	365°F. I	365°F. F	350°F. I	350°F. F
Natural Burnt Sienna	110	130	190	230	375	420
Light Precipitated Pure Red Iron Oxide	100	115	180	210	345	405
Light Calcined Pure Red Iron Oxide (Type I)	100	120	170	210	335	405
Blended Brown Iron Oxide	100	110	160	190	315	380
Extra Light Calcined Pure Red Iron Oxide (Type II)	90	120	160	200	315	385
Medium Calcined Pure Red Iron Oxide (Type I)	90	120	160	190	300	375
Natural Burnt Umber	70	110	150	190	310	375
Dark Precipitated Pure Red Iron Oxide	90	110	160	180	295	370
Light Precipitated Pure Yellow Iron Oxide	90	100	160	180	300	345
Dark Calcined Pure Red Iron Oxide (Type II)	85	100	150	180	270	340
Dark Precipitated Pure Yellow Iron Oxide	80	90	140	170	270	330
No Color Pigment	Salmon* at 70	Dark Tan* at 140	Salmon* at 100	Dark Tan* at 230	Yellow* at 180	Dark Tan* at 450

I = Initial time of discoloration (minutes).
F = Final time for complete top surface discoloration (minutes).
* These are gradual color changes from an opaque white natural-colored stock.

Table 4. Comparison of Stabilizers and Fillers. See Full Color Comparison on Page 538, Figure 3

Polyvinyl Chloride-Acetate	**100**
DOP	**30**
Epoxidized Soybean Oil	**5**
Stearic Acid	**0.25**
Light Calcined Pure Red Iron Oxide	**5**

Mix No.	Stabilizer & Filler		380°F. I	380°F. F	365°F. I	365°F. F	350°F. I	350°F. F
11	Tetrabasic Lead Fumarate Water Ground Calcium Carbonate	3 50	100	115	195	220	330	420
12	Tetrabasic Lead Fumarate Calcined Clay	3 50	90	100	150	195	295	330
13	Tetrabasic Lead Fumarate Uncalcined Clay	3 50	60	70	100	110	200	240
14	Dibasic Lead Phthalate Water Ground Calcium Carbonate	2 50	80	100	150	165	280	330
15	Dibasic Lead Phthalate Calcined Clay	2 50	60	70	110	120	200	240
16	Dibasic Lead Phthalate Uncalcined Clay	2 50	30	40	50	60	100	110

I = Initial time of discoloration (minutes).
F = Final time for complete top surface discoloration (minutes).

Comparing Various Iron Oxides

The iron oxide used in the preceding tests was a light calcined grade having 99+% ferric oxide content. Other grades of iron oxides were found to be very satisfactory and imparted somewhat varying stability to the plastic. Using composition No. 8 (*Table 2*) it was found that the lighter shades of iron oxide having the finer particle sizes are somewhat superior to the darker shades of the same pigment type. The darker shades have coarser particle sizes. The yellow iron oxides promote approximately the same stability as the darkest red iron oxides.

Burnt Sienna permits excellent stability and the stock containing Burnt Umber is stabilized as readily as those containing dark red iron oxides and slightly easier than those with yellow oxides (*Figure 2 and Table 3*). When times of initial peripheral discoloration are plotted against test temperature, the lines form a family of curves that are very nearly parallel.

The effect of lower concentrations of iron oxide colors was also investigated. Reducing the iron oxide from 5 phr to 1 and 0.5 phr reduced the aging time somewhat. This confirmed earlier, unpublished work which showed compounds containing 13 phr iron oxide were somewhat more stable than similar ones containing 5 phr iron oxide. A tint stock of iron oxide with rutile titanium dioxide was also very stable.

Comparison of Fillers

Since the majority of iron oxides are opaque, they would most frequently be used in systems normally containing fillers. The value of $CaCO_3$ as a filler when compared with both calcined and uncalcined clay is very pronounced. *Table 4* shows these data and *Figure 3*, page 538 is a color picture of these changes, an example of the many test results obtained in this work.

Based on two tests with different lead stabilizers, calcium carbonate promoted from 10% to 40% longer stability than calcined clay and it promoted from 65% to 200% longer stability than the uncalcined clay tested. Earlier unpublished work using another grade of calcined clay and the same uncalcined clay showed comparable results with four additional stabilizers including tin and barium-cadmium types and also with no stabilizer added to the base compound. Caution:

Grades of calcium carbonate prepared by five manufacturers showed somewhat different effects. Some grades were from 10% to approximately 20% poorer, stability-wise, than the best calcium carbonate tested.

Table 5. Blending of Fillers Produces Stable Compositions

Polyvinyl Chloride-Acetate	**100**
DOP	**30**
Epoxidized Soybean Oil	**5**
Stearic Acid	**0.25**
Light Calcined Pure Red Iron Oxide	**5**
Stabilizer	**Shown**
Filler	**Shown**

Stabilizer & Filler		380°F.		365°F.	
		I	F	I	F
Tetrabasic Lead Fumarate	3	100	125	195	230
Water Ground $CaCO_3$	50				
Tetrabasic Lead Fumarate	3	100	125	195	225
Water Ground $CaCO_3$	25				
Calcined Clay	25				
Tetrabasic Lead Fumarate	3	90	100	150	180
Water Ground $CaCO_3$	25				
Uncalcined Clay	25				
Tetrabasic Lead Fumarate	3	90	110	165	195
Precipitated $CaCO_3$	25				
Calcined Clay	25				
Dibasic Lead Phthalate	2	80	90	150	165
Water Ground $CaCO_3$	25				
Calcined Clay	25				
Mercaptotin Liquid	2	60	70	120	135
Water Ground $CaCO_3$	25				
Calcined Clay	25				
Ba-Cd (Phenate type) liquid	3	60	80	120	140
Water Ground $CaCO_3$	25				
Calcined Clay	25				
Tetrabasic Lead Fumarate	3	115	140	210	270
Precipitated Hydrated Calcium Silicate	50				

I = Initial time of discoloration (minutes).
F = Final time for complete top surface discoloration (minutes).

Table 6. Asbestos Fillers Produce Stable Stocks

Polyvinyl Chloride-Acetate	**100**
DOP	**30**
Epoxidized Soybean Oil	**5**
Stearic Acid	**0.25**
Light Calcined Pure Red Iron Oxide	**5**
Stabilizer	**Shown**
Filler	**Shown**

Stabilizer & Filler		380°F.		365°F.	
		I	F	I	F
Tetrabasic Lead Fumarate	3	100	120	195	225
Water Ground $CaCO_3$	50				
Tetrabasic Lead Fumarate	3	90	100	165	195
Asbestos	50				
Dibasic Lead Phthalate	2	90	110	165	210
Asbestos	50				
Ba-Cd (Phenate Type) liquid	3	80	90	145	165
Asbestos	50				
Mercaptotin Liquid	2	90	110	150	210
Asbestos	50				

I = Initial time of discoloration (minutes).
F = Final time for complete top surface discoloration (minutes).

Guide for Compounding Vinyl Plastics

—Continued

Blending of fillers is effective. Combinations of equal parts of $CaCO_3$ and calcined clay produced stabilities between those produced by either filler separately. This shows that the stability of a compound requiring clay filler can be improved by using some calcium carbonate also. Precipitated hydrated calcium silicate produced exceptionally good stability (*Table 5*).

Asbestos fillers produced stable stocks nearly as good as $CaCO_3$. This is shown with four separate stabilizers in *Table 6*.

Table 7. How Stabilizers Affect Stability of Stocks

Polyvinyl Chloride-Acetate	100
DOP	30
Epoxidized Soybean Oil	5
Stearic Acid	0.25
Light Calcined Pure Red Iron Oxide	5
Stabilizer	Shown
Water Ground $CaCO_3$	50

Stabilizer		380°F.		365°F.		350°F.	
		I	F	I	F	I	F
Tetrabasic Lead Fumarate	3	100	130	195	230	340	435
Dibasic Lead Phosphite	2	80	95	150	195	260	340
Dibasic Lead Phthalate	2	90	100	155	185	275	320
Dibasic Lead Stearate	2.5	85	95	150	185	250	320
Lead Orthosilicate-Silica Gel	2	50	60	100	110	160	200
Tribasic Lead Sulfate (hydrous)	2	85	95	150	180	250	300
Lead Chlorosilicate Complex	3	60	80	95	130	185	—
Dibutyl Tin Maleate (solid)	2	60	80	110	130	180	240
Mercaptotin (liquid)	2	75	90	135	195	240	300
Modified Tin Maleate (liquid)	3	65	75	110	130	190	225
Barium-Zinc	5	70	90	120	195	195	300
Barium-Cadmium plus Zinc "A"	2	55	65	95	120	160	200
All organic light Stabilizer	2	55	70	100	140	155	250
Ba-Cd Organic (liquid) "B"	3	55	70	100	120	165	195
Ba-Cd, Non-fatty Acid (liquid) "C"	3	60	75	100	125	165	210
Ba-Cd (liquid) "A"	2	55	65	100	120	165	210
Ba-Cd, Phenate type (liquid) "D"	3	65	80	110	140	185	230
Alkyl-Aryl Phosphite (liquid)	1	55	70	100	120	155	210
Ba-Cd Laurate (solid) "E"	1						
Organic Inhibitor	1	60	75	95	130	170	220
Ba-Cd (solid) "G"	1						
Strontium-Zinc Laurate	3	50	75	95	135	150	210
Ba-Cd-Zn (liquid) "D"	3	50	60	100	135	165	180
No Stabilizer	0	40	55	65	85	115	130

Letters A, B, C, D, E, G, refer to different suppliers of the various barium-cadmium compounds used.
I = Initial time of discoloration (minutes).
F = Final time for complete top surface discoloration (minutes).

Study of Stabilizers

Twenty-one stabilizers selected from the most popular commercial stabilizer classifications are reported in *Table 7*. In general, the lead stabilizers were superior, tins were generally somewhat poorer and barium-cadmiums imparted satisfactory but still less stability in these filled compositions containing iron oxides. Some of the zinc stabilizers were also satisfactory and others were actually detrimental.

More recent work has indicated that this generalization may not be completely valid with unfilled compositions containing iron oxides.

Table 8. Stabilities of Four Rigid Vinyl Compositions Pigmented with Iron Oxide

Polyvinyl Chloride-Acetate	100
Stearic Acid	0.25
Light Calcined Pure Red Iron Oxide	5
Stabilizer	Shown
Water Ground $CaCO_3$	50

Stabilizer		380°F.		365°F.		350°F.	
		I	F	I	F	I	F
Tetrabasic Lead Fumarate	3	45	60	105	120	175	190
Ba-Cd (Phenate Type) Liquid	3	<20	<20	25	30	50	50
Mercaptotin (Liquid)	2	40	40	60	75	100	130
Dibasic Lead Phthalate	2	40	40	70	75	115	130

I = Initial time of discoloration (minutes).
F = Final time for complete top surface discoloration (minutes).

Rigid Compositions

Stabilities of four rigid compositions pigmented with iron oxide were determined. Those with tetrabasic lead fumarate, dibasic lead phthalate and mercaptotin liquid were good and the one with barium-cadmium complex liquid was rated as fair (*Table 8*).

It is interesting to note that Jennings and Parks, in U. S. Patent 2,902,460 cite iron oxide as a stabilizer in certain rigid polyvinyl halide compositions.

Table 9. Effects of Varying Plasticizer Content

Polyvinyl Chloride-Acetate	100
Plasticizer	35
Stearic Acid	0.25
Light Calcined Pure Red Iron Oxide	5
Tetrabasic Lead Fumarate	3
Water Ground $CaCO_3$	50

Plasticizer		380°F.		365°F.	
		I	F	I	F
Di-(-2 ethylhexyl) phthalate Epoxidized Soybean Oil	30 5	120	140	195	225
Di-isooctyl phthalate Epoxidized Soybean Oil	30 5	100	130	150	195
Octyl-decyl phthalate Epoxidized Soybean Oil	30 5	130	165	210	270
Di-decyl phthalate Epoxidized Soybean Oil	30 5	70	110	105	165
Blend (1:1) isooctyl and isodecyl phthalate Epoxidized Soybean Oil	30 5	110	130	165	180
Tricresyl phosphate Epoxidized Soybean Oil	30 5	130	130	195	210
Di-(-2 ethylhexyl) phthalate Epoxidized Soybean Oil Di-(-2 ethylhexyl) adipate	25 5 5	70	90	105	135
Di-(-2 ethylhexyl) phthalate Epoxidized Soybean Oil Dioctyl sebacate	25 5 5	70	90	90	120
Di-(-2 ethylhexyl) phthalate Epoxidized Soybean Oil Di-(-2 ethylhexyl) Azelate	25 5 5	70	90	90	135
Di-(-2 ethylhexyl) phthalate Epoxidized Soybean Oil Chlorinated Diphenyl	25 5 5	65	80	90	120
Di-(-2 ethylhexyl) phthalate Epoxidized Soybean Oil Secondary Plasticizer-type undisclosed	25 5 5	70	90	90	120
Polymeric Plasticizer "A" Epoxidized Soybean Oil	30 5	150	165	255	285
Polymeric Plasticizer "B" Epoxidized Soybean Oil	30 5	180	200	285	300
Di-(-2 ethylhexyl) phthalate Epoxidized Soybean Oil "C"	30 5	120	140	195	225
Di-(-2 ethylhexyl) phthalate Epoxidized Soybean Oil "D"	30 5	110	140	180	210
Epoxidized Soybean Oil	35	210	>230	300	>345
Epoxidized Soybean Oil "D"	35	210	>230	300	>345

Letters A, B, C, D, refer to different suppliers of the plasticizers.
I = Initial time of discoloration (minutes).
F = Final time for complete top surface discoloration (minutes).

Effects of Plasticizers

Table 9 shows effects of varying the plasticizer content of iron oxide pigmented composition No. 8 (*Table 2*) containing 30 phr DOP and 5 phr epoxidized soybean oil. Separately substituting three other phthalates produced shorter aging times while a fourth phthalate increased the life and a phosphate did not affect it. Five secondary plasticizers separately substituted for a like amount of DOP (5 phr) substantially reduced aging life. Use of all polymeric plasticizers again (as in *Table 2*) shows substantially improved aging and substitution of two other grades of commercial epoxidized soybean oil replacing the one previously used showed no significant variations.

In addition to these plasticizers shown in the table it was found that butyl benzyl phthalate, butyl decyl phthalate and butyl octyl phthalate promote the same stability as dioctyl phthalate.

Resin Type

Similar iron oxide colored compositions to those presented thus far but employing resins containing higher portions of vinyl acetate, such as 13%, may have only a third of the stability of the preceding compounds containing resins with 2.5% vinyl acetate content. However, use of straight polyvinyl chloride resins usually further improves stability up to 30%, as far as has been tested. Included in the polyvinyl chloride resin group was one of a dispersion type.

A comparison of the effect of thickness of samples (0.04" vs. 0.08") showed no significant effect on aging time. The thinner samples were only marginally faster in a small proportion of tests.

Study of Recycling

It was desired to evaluate the effects of remilling partially aged compositions to determine if unexpected characteristics would be developed by processing conditions such as recycling of scrap. Five stocks were prepared on the two-roll mill as described in the opening paragraphs, divided into several portions and processed as follows:

(a) Oven stability was run as usual.

(b) One portion was exposed to the oven for approximately 50% of its life as determined in (a).

(c) Part of (b) was remilled, remolded and oven aged. Aging life equal to 50% or less of that obtained in (a) was expected. However, aging periods of 65%, 70%, 75%, 80% and 85% of the respective times reported in (a) were obtained.

(d) Part of (b) was remilled with equal quantities of unaged stock, molded and oven aged. Aging life equal to 75% or less of that obtained in (a) was expected. However, aging periods of 75%, 80%, 90%, 95% and 100% of the respective times reported in (a) were obtained.

These values are detailed in *Table 10*. It is apparent that recycling will not present stability problems with these compositions containing iron oxide pigments.

Correlation With Mill Tests

To obtain a brief correlation of the preceding oven tests with mill tests, four compositions containing iron oxide were prepared wherein stock temperatures were 340°F. immediately after fluxing and 350°F. fifteen minutes after start of operations. Using composition No. 4 (*Table 2*) some adhesion to the roll developed at 35 minutes of continuous milling and no further change occurred until 118 minutes of mixing when an initial and substantial discoloration suddenly appeared and falling from the rolls took place. With composition No. 5, adhesion developed at 65 minutes and discoloration and falling occurred at 250 minutes. Adhesion developed with composition No. 6 at 150 minutes and it did not become discolored or unmillable until a total of 238 minutes of continuous milling elapsed. A comparable mix containing 2 phr dibasic lead phosphite showed some adhesion at 40 minutes and it milled without color change for 335 minutes. In all cases, acid fumes were not detected until within a couple minutes of the end of milling. Therefore, it may be concluded that the color stabilities of these stocks are excellent and that they remain millable on the two-roll mill for at least as long as it takes to produce initial peripheral discoloration in the forced-draft oven at the same temperature, 350°F.

Table 10. Recycling does not Present Stability Problems with Compositions Containing Iron Oxide Pigments

Polyvinyl Chloride-Acetate	100
DOP	30
Epoxidized Soybean Oil	5
Stearic Acid	0.25
Light Calcined Pure Red Iron Oxide	5
Stabilizer	Shown
Water Ground $CaCO_3$	50

Stabilizer		Test Variation	365°F. I	365°F. F
No Stabilizer	0	(a) As Is	60	85
		(b) Oven heated 35 min.	50	70
		(c) Oven heated 35 min. and blended 50:50 with unaged stock	70	80
Tetrabasic Lead Fumarate	3	(a) As Is	200	240
		(b) Oven heated 100 min.	160	180
		(c) Oven heated 100 min. and blended 50:50 with unaged stock	190	215
Dibasic Lead Phthalate	2	(a) As Is	170	190
		(b) Oven heated 80 min.	110	120
		(c) Oven heated 80 min. and blended 50:50 with unaged stock	130	155
Barium-Cadmium Liquid (Phenate type)	3	(a) As Is	100	140
		(b) Oven heated 60 min.	70	90
		(c) Oven heated 60 min. and blended 50:50 with unaged stock	90	110
Mercaptotin Liquid	2	(a) As Is	120	160
		(b) Oven heated 70 min.	90	110
		(c) Oven heated 70 min. and blended 50:50 with unaged stock	110	130

I = Initial time of discoloration (minutes).
F = Final time for complete top surface discoloration (minutes).

Conclusions

The following broad summary is concluded from this work:

(1) A wide variety of iron oxides can be readily stabilized in many vinyl systems using a broad range of commercial grade compounding ingredients.

(2) All classes of stabilizers may be used, some with greater effectiveness than others. However, not every stabilizer within each class imparts good stability to vinyl plastics colored with iron oxide pigments and the selection must be made primarily on a trial and error basis.

(3) Use of calcium carbonate as a filler is very effective.

(4) Use of epoxy compounds is generally desirable.

(5) Polymeric plasticizers are also effective in imparting good heat stability to vinyl plastics colored with iron oxide pigments.

Properties and Applications

Heat-Shrinkable and Polymer-Coated Polyester Films

Paul Stephan, *Film Dept., E. I. du Pont de Nemours & Co., Inc.*

A modified version of polyester film laminate which has applications in food packaging.

Polyester film is already well known in the packaging and plastics industries for its physical strength, chemical resistance, wide thermal range and dielectric strength. But with current trends toward more specialization in packaging, there has been a growing need for the unusual characteristics of this film in certain applications where the original version was not suitable. As a result, "Mylar" polyester film has now been modified and is available in two additional forms; one which is heat shrinkable and another which is polymer coated. This article reviews these new films in the light of development work which has established their characteristics, properties, and applications.

Basically, this polyester film is an oriented material of polyethylene terephthalate, in which the orientation produces a "balanced" sheet with uniform properties in all directions. The film is prepared from the condensation polymer of ethylene glycol and terephthalic acid. In this article, the term "polyester film" will refer to this material made by Du Pont.

HEAT SHRINKABLE POLYESTER FILM

Heat shrinkable polyester film overcomes the limitations of low-temperature durability and variable clarity and offers many other outstanding properties. The shrinkable film differs from its familiar parent material only in its sensitivity to heat.

From a packaging standpoint, all properties are essentially the same as those of the standard polyester film.

Properties

Mechanical

Heat shrinkable polyester film has a tensile strength of approximately 18,500 p.s.i. prior to shrinkage. *Table 1* compares physical properties with those of other packaging materials.

The film contains no plasticizers or softeners. Thus, flexibility, as well as other physical properties, is far less sensitive to changes in temperature and humidity.

The material shrinks approximately 25 to 30 per cent uniformly in each direction. *Shrinkage increases gradually from none at 140°F. to a practical maximum of 25 to 30 per cent at 212°F. Shrinkage is instantaneous.* The film increases in gauge from 0.5 to a maximum of 0.9-1.1 mils upon complete shrinkage at 212°F., thus improving the barrier characteristics of the material.

Durability through a wide range of temperatures (−80°F. to 300°F.) is another key feature of the film. Even when exposed to liquid nitrogen temperatures (−300°F.), film samples were not embrittled.

Tear and puncture resistance of the film, though not comparable with softer, more elastic films, nevertheless is at a satisfactory high level.

Although the film has a modulus of about 579,000 p.s.i., it still has a high flex life.

Thermal

The remarkable stability and strength of the film over a wide temperature range has just been outlined. However, the effects of prolonged exposure to very high temperatures (300°F. and up) have not been established specifically

Table 1. Properties of Heat Shrinkable Polyesters Compared with other Packaging Materials

Property	Heat Shrinkable Polyester Film		Standard Polyester Film	Cellulose Acetate	Cellophane
	(1) B.S.	(2) A.S.			
Thickness, Mils	0.5	0.9-1.1	1.0	0.88	1.0
Tensile Strength p.s.i.	18,500	14,400	23,500	9,000	8,000
Elongation, %	84	179	70	20	30
Tensile Modulus p.s.i.	579,000	395,000	500,000	350,000	400,000
Tear, Gms.	11.7	33.2	18	4	5
Impact, Kg-CM	36	121	90	10	15
Flex, Cycles	20,000	9,700	20,000	300	600

(1) B.S.—Before Shrinkage (2) A.S.—After Shrinkage at 212°F.

This article was adapted from a paper presented at the SPE Golden Gate Regional Technical Conference (RETEC), November 19, 1959

HEAT SEALING and PRINTING

The high softening point and heat sensitivity of heat shrinkable polyester film have presented problems in heat sealability by conventional means. However, there are several specialized methods of obtaining a satisfactory seal.

For one, benzyl alcohol in combination with heat and pressure provides adequate sealing–both for strength and for impact resistance. Also, the use of adhesives or heat sealable coatings, printed onto the specific area of the film where the seal is to be made, has proven quite satisfactory and is the technique now used to fabricate bags. Another technique involving close control of heat and pressure permits heat-sealing the film to itself without any pretreatment for sealing.

These various sealing techniques permit the film to be sealed by semi- or fully-automatic equipment. Many other sealing methods were evaluated by the laboratory, but these proved to be the most practical.

The film can be printed satisfactorily either by flexographic or gravure techniques with inks already available for standard polyester film. Legend distortion is kept at a minimum because of the uniform film shrink pattern.

for this heat shrinkable polyester film. But it is expected to behave in a manner similar to the parent film. In the case of the standard polyester film under such high temperatures, some degradation of mechanical strength occurs, although the strength level remains remarkably high.

Chemical

Chemical resistance of the heat-shrinkable polyester is similar to the resistance of the standard polyester film. Many food products are packed in brines or syrups, and others are themselves composed of chemicals which exert a degrading or corrosive effect on the packaging material. Thus, the inertness of this polyester film is valuable in many ways.

Packaging

The permeability characteristics, both water vapor and gas, are shown in *Tables 2, 3, and 4.*

The water vapor permeability of this polyester film at room temperature is relatively high, but it borders on complete impermeability at 32°F. and below. For this reason, it offers good protection to frozen foods. Shelf lives for frozen poultry and vegetables packed in 50-gauge heat shrinkable polyester film are currently being established by the Du Pont laboratory.

The gas barrier characteristics of the film are excellent for many applications. Comparative data developed in our laboratory are tabulated in *Table 4.* Changes in humidity result in relatively minor changes in permeability. Protection from fading of product color where both light and oxygen permeability are factors is essentially equivalent to other shrinkable films.

Good resistance to the passage of odors and grease are other key features of the film. *Table 5* illustrates the odor permeability of the heat shrinkable film. From a practical standpoint, resistance to odor transmission is of particular value in food products where volatile flavors and odors are involved. It also minimizes the possibility that products packaged in the film will absorb odors from other items with which they might be stored.

The film transmits more than 90 per cent of the incident light in the visible region of the spectrum. In the ultra-violet range, it cuts off at 3,100 to 3,200 angstroms. The film is similar to window glass with respect to ultra-violet transmission.

Because the material is odorless and non-toxic, it may be used in direct contact with food products. Data on extraction and feeding tests of this polyester film have been

Table 2. Effect of Temperature on the Moisture Permeability of Heat Shrinkable Polyester Film

Film Thickness (Inches x 10^{-3})	M.V.T.R. (Gms./100 sq. M./Hr.)	
	4.4°C./2.2 mm. Hg. V.P.D.	39.5°C./53 mm. Hg. V.P.D.
0.50	20	300-320

Table 3. Effect of Shrinkage on the Moisture Permeability of Heat Shrinkage Polyester Film

	Before Shrinkage	After Shrinkage
Film Thickness	0.5	0.9-1.1
M.V.T.R. (Gms./100 sq. M./Hr. at 39.5°C./53 mm Hg. V.P.D.)	300-320	205

Table 4. Gas Permeability (1) of Heat Shrinkable Polyester Film

	Carbon Dioxide		Oxygen	
Film	2% R.H.	98% R.H.	2% R.H.	98% R.H.
1 mil MSAD Cellophane	4.73	44.29	0.58	18.91
0.5 mil Std. "Mylar"	3.15	11.03	1.72	4.58
0.5 mil Heat Shrinkable "Mylar"				
Before Shrinkage	—	9.5	—	3.5
After Shrinkage	—	5.3	—	3.4

(1) In gms./100 sq. M./Hr. at 75°F.
V.P.D.—760 MM Hg. at 2% R.H.
V.P.D.—738 MM Hg. at 98% R.H.

Table 5. Odor Permeability (Time in Hours to Nasal Perception)

	0.5 mil Heat Shrinkable "Mylar"
Methyl Salicylate	20
Ethyl Butyrate	2
Propylene Diamine (1)	4

(1) Propylene diamine has a degrading effect on the film.

Table 6. Properties of Heat Sealable Polyester Film Types 50 K-22 and 50 K-23

Base Sheet: 50 polyester film

Coated Film Thickness: about 0.75 mil. coating on both sides

Yield: approximately 27,500 sq. in./lb.

Price: $2.50/lb., which calculates to about 9.1¢/1,000 sq. in.

Moisture Vapor Transmission: 40-60 g./100 sq. m./hr. (Du Pont method, 39.5°C.); unaffected by age, grease and reasonable handling.

Heat Sealability: essentially the same as K-type cellophane; i.e., at 325-350°F. with a hand sealing iron, preferably through glass cloth coated with "Teflon" TFE-fluorocarbon resin (aqueous dispersion). Seals are essentially insensitive to age, moisture, and grease. They are not appreciably affected by temperatures of 0-120°F.

Strength Characteristics: These films offer good durability for this thickness of film. Wide ranges of temperature and humidity or long periods of storage, transit, and display do not affect durability.

presented to the Food and Drug Administration of the U. S. Department of Health, Education, and Welfare. *The Administration has stated that these data indicate that the film is acceptable for packaging in food and drug uses for temperatures up to 250°F.* Clearance for this polyester film on meat products has also been received from the Meat Inspection Branch of the U. S. Department of Agriculture. Clearance for the adhesives used in fabricating bags and tubes of the heat shrinkable film has also been obtained from the same agencies.

Standard polyester film has been exposed to both pasteurizing and sterilizing doses of irradiation with no significant effect on its mechanical or physical properties. The heat shrinkable variety would be expected to behave similarly.

Applications

Basic applications for the film, usually in the form of tubes and contour-bottom bags, are at present confined to the food industry (smoked meats, poultry, etc.) although considerable interest has been received for several non-food packaging applications.

The use of the film in bag form involves five basic steps:

1. Inversion of the bag (turning it inside out) to improve seal strength and package appearance.
2. Loading of the product into the bag—this step is carried out at the same time the bag is inverted.
3. Evacuation of air from the package.
4. Closure.
5. Shrinkage in water at 208-212°F.

Inversion and loading are accomplished in a single operation.

Air is evacuated from the package mechanically. This step not only assists in film conformation to the product, but also aids in product protection.

Airtight closures are essential to package appearance and to product protection. Such closures can be obtained with standard fastening devices.

Immersion in water at 208-212°F. is the most practical way to shrink the film. Either batch or continuous shrinkage equipment at these temperatures provides satisfactory results. Other shrinkage techniques (hot air, infra red lamps, microwaves, etc.) have been investigated on a limited basis, but their practicality depends on the product to be packaged. Equipment for evacuation and shrinkage is obtainable on a commercial basis from several manufacturers.

Heat shrinkable polyester film is available in 50 gauge (0.5 mil) only in rolls from ½ inch to 55 inches wide and in cut-to-size sheets in any other dimensions. The yield is 40,000 square inches per pound.

In converted form—plain or printed tubes—the film is available in either continuous or cut-to-size tubing, and in contour-bottom bags.

Although the bulk of this development effort has been directed toward the smoked meat and poultry fields, many other possibilities exist for further applications.

POLYMER COATED POLYESTER FILM

There are three polymer coated types of polyester film which have been developed by Du Pont: M-22, M-23, and M-24. M-22 and M-23 are coated on both sides, whereas M-24 is a one-side-coated film.

M-22 is especially designed for bag-making (either by hand or machine). Its particular type of double-coated construction provides a surface which is easily heat sealed, yet will withstand the stresses to which a bag seal is often subjected. Under conditions of handling, dropping, or shipping, these durable bags hold their contents firmly.

For this reason, bags of this material are used in the confection industry and other industries where clearly displayed bulk units of a product are desired. Bags made from this film have been utilized, for example, in packaging two-pound or larger units of hard candy—providing an acceptable transparent bag for a heavy, many-unit package. Candy makers report that the film has sufficient transparency, sparkle and flexibility, and that it has solved their winter bag-breakage problem.

M-23 polyester film is particularly well suited for bundling and overwrapping of various products. This material is constructed in a different manner from M-22 in order to provide features necessary for this type of operation. Here again, the strength of this film makes it particularly useful in solving breakage problems often encountered with other films used for these purposes. Yet its clarity gives at least the same level of display attractiveness. A greeting card manufacturer, who is one of the users of this film, has found that his Christmas card package-breakage problem has been solved by the film, which, even under severe cold weather conditions, long shelf life, and frequent handling, will not grow brittle or break.

The M-24 form of the film is coated on only one side, and is intended for lamination or coating with other materials, such as polyethylene. It has found wide acceptance for vacuum or inert gas packaging of meat and cheese products.

These polymer-coated polyester films were developed to meet the need for a film with the durability of polyester film, coupled with its outstanding moisture and gas barrier properties, which could be heat sealed by conventional means.

Table 6 illustrates the properties which have been achieved for 50 M-22 and 50 M-23. Similar data for 50 M-24 would depend on the material to which it is bonded by laminating or extrusion coating.

In summary, polymer coated types of polyester film are being used principally in the food packaging field where the need for such films has been great. However, non-food applications for the film are now being explored.

Urethane polymers have properties which suggest their use in the shoe industry. Urethane elastomers are being used to make heel lifts and are showing interesting possibilities for certain types of soles. Urethane coatings are being used to give leather an extremely durable finish that requires no subsequent buffing or polishing.

Urethanes in the Shoe Industry

G. A. Baseden

E. I. du Pont de Nemours & Co., Inc.
Elastomer Chemicals Department

Polymers that contain urethane groups have outstanding physical properties. They are versatile and may be used to prepare elastomers, adhesives, coatings, resilient and rigid foams.

The urethane group is the reaction product of an isocyanate with a hydroxyl.

$$-N=C=O + H-O- \rightarrow -N(H)-C(=O)-O-$$

Urethane polymers may be prepared by reacting a diisocyanate (e.g. toluene diisocyanate) with a low molecular weight resin containing two or more hydroxyl groups per molecule. By suitable stoichiometry a high molecular weight polymer is obtained with repeating urethane linkages along the polymer chain. The properties of the polymer may be controlled over wide limits by suitable choice of the hydroxyl-containing resin.

This article is limited to a discussion of elastomers prepared from liquid urethane polymers and urethane coatings in the shoe industry.

URETHANE ELASTOMERS

The oustanding properties of the urethanes are strength, load bearing capacity and abrasion resistance, combined with heat and oil resistance. In principle, the urethanes should be considered for uses where conventional elastomers fail by abrasion or physical abuse.

For several years, urethane elastomers have been available to the shoe industry as solid millable polymers. They were compounded and processed like any other solid elastomer. Now liquid urethane elastomers are available in a series of three polymers which give vulcanizate properties that are superior to those of the solid urethanes, and which may be varied over much wider limits. At the same time, being liquids, they can be cast in molds, a method of processing that is well suited to automated production.

These castable liquids are prepared by reacting toluene diisocyanate with a polyether glycol to give low molecular weight isocyanate-terminated polymers. *Table 1* describes their physical properties.

Table 1. Physical Properties

	ADIPRENE* L-100	ADIPRENE* L-167	LD-213
Specific Gravity	1.06	1.06	1.15
Isocyanate Content	4.0-4.3%	6.2-6.5%	9.2-9.5%
Viscosity at 86°F., cps	14000-19000	6000-8000	12000-18000
Viscosity at 212°F., cps	500-600	250-350	300-400
Odor	None	Faint Isocyanate	Faint Isocyanate
Appearance	Honey-colored liquids		
Storage Stability	Excellent at room temperature		
Solubility	Soluble in most common solvents		

* Registered trademark for Du Pont urethane elastomers.

This article adapted from a paper presented at the Regional Technical Conference in St. Louis, November 4, 1959.

Curing Agents

These three urethane polymers may be cured by most materials that have a molecular structure containing two or more reactive hydrogen atoms. Vulcanizate properties will depend to a large extent on the type of curing agent used. MOCA (4, 4'-methylene-bis (2-chloro-aniline), is recommended as a curing agent for these three polymers because of ease of processing and best all-around vulcanizate properties. It has a melting range of 212-220°F and is very soluble in dimethyl formamide.

Processing

Processing is carried out by mixing molten MOCA with the liquid urethane polymer, degassing the mixture and pouring or injecting it into a mold. Fastest production and best properties are obtained by heating the mixture in the mold, but this is not always necessary.

A similar process has been used for several years with liquid epoxy resins. In consequence there are a number of reliable machines available to process liquid urethane elastomers.

The advantages of liquid molding versus solid molding for elastomers may be summed up:

(1) Lower capital investment.
(2) A process suitable for automated production.

The liquid urethanes may also be converted to solid millable gum stocks, with no loss in vulcanizate properties, when the manufacturer prefers to use conventional molding processes. The conversion is carried out by pouring the degassed polymer/MOCA blend on a flat tray to the desired thickness and allowing to solidify at room temperature for the following recommended times:

ADIPRENE L-100 + 11 parts of MOCA	8-10 hours
ADIPRENE L-167 + 20 parts of MOCA	1- 2 hours
LD-213 + 30 parts of MOCA	5-10 minutes

The sheet is then stripped from the tray and processed as if it had come from a mill. The process has been demonstrated on a laboratory scale but has not yet been developed in production.

Vulcanizate Properties

The vulcanizate properties of these three liquid urethane polymers cured with MOCA, are shown in *Table 2*. The compounds described are not necessarily the best for use in the shoe industry, but are representative compounds for general use.

Table 2 shows that the characteristic properties of MOCA-cured vulcanizates from these three liquid polymers are high tensile strength and abrasion resistance, and a combination of extensibility and high hardness which is unobtainable with conventional elastomers.

Reactivity increases, as shown by decreasing pot life, with increasing isocyanate content of the liquid polymer. Batch mixing is possible for ADIPRENE L-100, but the pot life of ADIPRENE L-167 and LD-213 is so short that machine mixing is usually necessary.

Table 2. Vulcanizate Properties of Adiprene L-100, Adiprene L-167, LD-213

	FORMULA		
ADIPRENE L-100	100	—	—
ADIPRENE L-167	—	100	—
LD-213	—	—	100
MOCA	11	20	25
Pot Life, min. @ 212°F	12	4	2
Cure, hrs./°F.	3/212	1/212	1/212
	PROPERTIES		
Modulus @ 100%, psi[1]	1000	1800	3800
Tensile Strength, psi[1]	5000	5200	8000
Elongation at Break, %	450	480	270
Hardness, Shore A	90	95	100
Hardness, Shore D	45	50	78
Pressure @ 5% Deflection, psi	300	375	1375
Bureau of Standards Abrasion Index, %	129	230	325
Volume Swell in ASTM #3 oil, %[2]	18.1	13.4	13.5
Oxygen and ozone resistance	Excellent		

(1) Pulled @ 40"/min. for ADIPRENE L-100 and L-167. At 1"/min. for LD-213.
(2) Immersed 7 days @ 212°F.

Chemical Compounding

The liquid urethanes may be compounded with carbon black, and in general vulcanizate properties may be modified by the additions of fillers and stabilizers.

Chemical compounding, however, provides a convenient means of varying the vulcanizate properties of the liquid

Table 3. Variation of MOCA Concentration

	FORMULA				
ADIPRENE L-100	100	100	100	100	100
MOCA	6	9	11	13	15
	Mixed at 212°F. Cured three hours at 212°F.				
	PROPERTIES				
Modulus @ 300%, psi	2600	2575	2100	1975	1075
Tensile Strength, psi	3500	3875	4500	4175	1200
Elongation @ Break, %	350	350	440	480	600
Hardness, Shore A	86	89	90	88	88
Ross Flex, hrs. to 5X cut growth	0.5	0.5	1.0	4.5	100+
Bureau of Standards Abrasion Index, %	56	81	129	182	209

Table 4. Microcellular Products From Adiprene L-100

Compound	FORMULA 1	2	3	4
ADIPRENE L-100	100	100	100	100
Cab-O-Sil	3	5	5	3
DC-200	2.5	2.5	2.5	2.5
MOCA	12	12	12	12
NITROSAN*	—	—	—	0.5
Water	0.25	—	—	—
FREON-113	—	2	4	—
Expanded and cured for three hours at 212°F.				
	PROPERTIES			
Specific Gravity	0.685	0.650	0.473	0.445
% Closed Cells	73	81	48	55
Comp. Set "A", 50% Defl. (SPI), 22 hrs./158°F., %	19.2	14.0	7.8	7.6
Comp. Defl., psi @ 25% Defl.	226	260	107	97
Tensile Strength, psi	735	849	406	226
Elongation @ Break, %	280	360	230	200
Materials Cost, $/cu. ft	51.00	47.70	34.35	33.65

* Chemical blowing agent. Du Pont registered trademark. Added as a 50% dispersion in Flexol 1010.

urethanes over very wide ranges. It consists of altering the molecular structure of the vulcanizate by varying:

(1) Mixing and/or curing temperature.
(2) Type of curing agent.
(3) Proportion of curing agent.

For example, the Shore A hardness of fully cured ADIPRENE L-100 vulcanizates, containing 11 parts of MOCA, can be varied from 60 to 92 just by varying mixing and curing temperatures. By varying all three of the above factors, a complete range of ADIPRENE L-100 vulcanizates varying from Shore A 10 to 90 in hardness may be obtained.

The effect of varying the proportion of MOCA in ADIPRENE L-100 vulcanizates is shown in *Table 3*.

The most convenient way of preparing very hard urethane elastomers (i.e. in excess of Shore A 90) is to use either ADIPRENE L-167 or LD-213. Vulcanizates from ADIPRENE L-167 may be prepared, by suitable choice of curing agent, with Shore A hardnesses ranging from 55 to 95. Similarly, with LD-213, a Shore D hardness range of from 43 to 78 may be obtained.

The liquid urethanes are inexpensive in terms of cost per unit of performance. When ADIPRENE L-167 cured with 20 parts of MOCA and a typical SBR formula for top lifts are compared, in terms of material cost per unit of abrasion index, the ADIPRENE L-167 formula is slightly less expensive than the SBR compound. The value of this approach to cost is dependent on the customer's desire for improved performance.

Urethane Sponge

A process that reduces volume costs has been developed. It consists of expanding the urethane polymer to a microcellular product, containing a large proportion of closed cells, by some method of generating gas within the polymer as it cures. There are three ways of doing this:

a)—Generating CO_2 by reacting free isocyanate groups with water;
b)—Adding a chemical blowing agent that liberates a gas when heated;
c)—Adding a low boiling liquid (FREON-113*) that produces small bubbles of vapor when subjected to cure temperatures.

Each of these three methods required the addition of a surface active agent, such as silicone oil DC-200 (50 centistokes grade)**, to give the desired cell structure. A filler such as Cab-O-Sil*** may be required to increase viscosity and aid gas retention until the polymer has set.

Table 4 illustrated typical properties that may be obtained from ADIPRENE L-100 by these three blowing methods.

The data in *Table 4* show that slightly better properties are obtained by blowing with FREON-113 than with water or NITROSAN. However, NITROSAN is preferred for ease of processing.

Table 5 compares the properties of sponges from ADIPRENE L-100 and L-167, and LD-213.

Table 5 shows some systematic changes in properties through the polymer series ADIPRENE L-100 to LD-213. These changes include:

(a) Load-bearing capacity per unit of specific gravity increases;
(b) Compression set increases.

Useful products may be prepared by this process from ADIPRENE L-100 or L-167, or LD-213, but for the shoe industry microcellular products from ADIPRENE L-100 or L-167 are more likely to be of interest because of their greater extensibility.

These compounds are in the development stage. Further work is necessary to find ways of decreasing specific gravity and increasing the proportion of closed cells. It is already apparent, however, that an important property of the urethane sponges is their exceptionally high load-bearing capacity and abrasion resistance.

* Registered trademark for Du Pont's fluorinated hydrocarbon compounds.

** Dow Corning Corporation.

*** Finely divided silica—Godfrey L. Cabot, Inc.

Table 5. Microcellular Products From Adiprene L-100, Adiprene L-167 and LD-213

Compound	4	5	6
ADIPRENE L-100	100	—	—
ADIPRENE L-167	—	100	—
LD-213	—	—	100
DC-200	2.5	2.5	2.5
MOCA	12	20	20
NITROSAN*	0.5	1.0	2.0
Cab-O-Sil	3.0	—	—
Expand and Cure, hrs./°F.	**3/212**	**1/212**	**1/212**
Specific Gravity	0.445	0.375	0.233
% Closed Cells	55	40	83
Comp. Set "A", 50% Defl. (SPI), 22 hrs./ 158°F., %	7.6	20.1	48.3
Comp. Defl., psi at 25% Defl.	97	102	165
Tensile Strength, psi	226	263	218
Elongation @ Break, %	200	200	45
Materials Cost, $/cu. ft.	33.65	28.40	17.70

* Added as a 50% dispersion in Flexol 1010.

Uses of Liquid Urethane Polymers

ADIPRENE L-100 has interesting possibilities as a shoe soling compound, particularly as it may be compounded to give a combination of excellent abrasion resistance and excellent resistance to cut growth on flexing.

The performance of ADIPRENE L-100 as a shoe soling compound is illustrated in *Table 6*, in which ADIPRENE L-100, cured with 15 parts of MOCA, is evaluated in a military specification.

In addition to the tests shown in *Table 6*, Ross Flex was measured with ASTM #3 Oil in the cut. The cut growth at 25,000 cycles was again 0%.

The recently introduced process of molded-on soles and heels may prove to be an excellent application for ADIPRENE L-100. One of the main difficulties in using solid elastomers in this process is conducting sufficient heat through the heel to cure it all the way through. This problem would not arise with ADIPRENE L-100, which may be injected at its curing temperature. It would only be necessary to maintain the temperature, with little or no heat conduction being required. Since ADIPRENE L-100 is a liquid, high molding pressures would be unnecessary. However, this application for ADIPRENE L-100 has yet to be developed.

ADIPRENE L-100 is also being evaluated as a binder for scrap leather.

The most promising application for ADIPRENE L-167 and LD-213, at the present time, is for heel lifts. The suggested formulations for this application are those given in *Table 7*.

The two formulae in *Table 7* represent the extremes in hardness that are of interest. Properties that are intermediate between these extremes may be readily obtained by blending the two urethanes or varying the cure temperature.

Heel lifts from ADIPRENE L-167 and LD-213 have shown themselves to be extremely durable. They have excellent abrasion resistance, very high impact resistance and they do not embrittle on aging or when cooled to low temperatures. They are also very resistant to cutting, chipping, splitting and feather edging.

Although not directly related to shoe construction, ADIPRENE L-100 parts may be used in production equipment to obtain longer life. Industrial rolls of ADIPRENE L-100 are being used in places where other elastomers failed by abrasion. An industrial roll in one of our plastics plants had a life of only about one month due to constant abrasion between the roll and the plastic. A replacement roll of ADIPRENE L-100 is still in new condition after five months' service.

At another plant, fork-lift truck tires made with conventional elastomers fail from abrasion and chipping after three weeks' service. Replacement tires of ADIPRENE L-100 are still in good condition after almost two years of the same service.

These examples suggest that the liquid urethanes may find a number of applications in shoe-making equipment.

URETHANE COATINGS

Urethane polymers, used as surface coatings, exhibit many desirable properties, including high abrasion and scuff resistance, excellent flexibility, freedom from embrittlement on aging or on cooling to low temperatures, good solvent resistance, and excellent adhesion to a variety of surfaces, including leather.

Urethane coatings are finding increasing use as a high grade patent finish for leather and offer interesting possibilities as a side leather coating.

Description

There are several types of urethane coatings that are commercially available. Two of these appear to have practical importance in the shoe industry.

(1) A one-package system consisting of an isocyanate terminated urethane polymer that is prepared by reacting toluene diisocyanate with a suitable polyhydroxy material such as a polyester, a polyether, or castor oil.

The film hardens by reaction with atmospheric moisture:

$$2\text{—N=C=O} + \text{H}_2\text{O} \rightarrow$$

$$\text{——N—C—N——} + \text{CO}_2$$

$$\begin{matrix} & | & \| & | & \\ & \text{H} & \text{O} & \text{H} & \end{matrix}$$

The film is sufficiently permeable to gases that the carbon dioxide that is liberated diffuses out without causing any blistering.

Table 6. Adiprene L-100, +15 Parts of MOCA, in MIL-S-40043

	Spec. for Classes 1-6	ADIPRENE L —100
Abrasion Index, %	40-50	220
Abrasion Index after aging[1], %	35-45	340
Shore A Hardness	72-85	88
Shore A Hardness after aging[1]	72-90	88
Cut growth after aging[1] at 25,000 flexes, %	500, %	0%
Volume Swell[2], %	40 max.	25

(1) 24 hours at 212°F.
(2) 46 hours in ASTM Reference Fuel B, at 75°F.

Table 7. Urethane Heel Lifts

	Heel Type	
	Non-Clicking	Clicking
ADIPRENE L-167	100	—
LD-213	—	100
MOCA	20	25
Cure, hrs./°F.	1/212	1/212
Hardness, Shore D	50	78
Bureau of Standards Abrasion Index, %	230	325

Table 8. Film Properties

	M.W. per cross-link	
	600	1100
Tack-free time, hrs.	1-2	16-20
Time to full cure, days	5	5
Sward Hardness	60	26
Pencil Hardness	H	3B
Tensile Strength, psi	6000	4000
Elongation @ Break, %	40	140
Taber Abrasion Index[1]		
CS-10 wheel, 1000 g. weight	75	50
Moisture vapor transmission[2]	130	140

(1) Taber Abraser—ASTM D-1044
Taber Index—milligrams weight loss/1000 revolutions.
(2) By ASTM E96, (100°F. @ 90% R.H.)
MVT = grams/sq. meter/day for film 10 mils thick.

Usually, in this type of coating, the film is tack-free in one to two hours at room temperature, and has achieved a good part of its final hardness after one day.

Much shorter tack-free times (5-15 minutes) and final cure times (6 hours) have been obtained by adding a catalyst.

Coatings of this type, formulated to give soft extensible films, take longer to become tack-free but the time to a complete cure shows little change.

(2) A two-package system. One part is a solution of a low molecular weight isocyanate-terminated urethane polymer. The other part is a polyol. The two parts are mixed immediately before application and the film hardens by reaction of isocyanate with hydroxyl groups. Tack-free time may be as short as ten minutes, and in five or ten more minutes, the film is tough enough to handle.

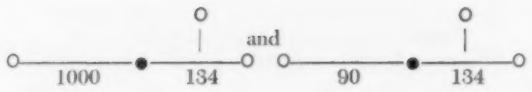
Formulation, Processing and Properties

The basic composition of a typical one-package urethane coating consists of the reaction product of:

	Moles
Polypropylene glycol (1000 M.W.)	1
1,3-Butanediol	1
Trimethylolpropane	2
HYLENE® TM toluene diisocyanate	8

together with additives such as a non-discoloring antioxidant and a flow control agent dissolved in a solvent blend—usually Cellosolve acetate and xylene.

The coating consists ideally of a solution of two low molecular weight isocyanate-terminated polymers with the following idealized structure:



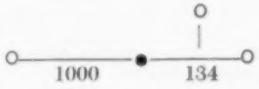
In these structures, the open circles represent urethane groups where only one of the two available —NCO groups on the HYLENE TM have been reacted; the solid circles represent toluene diisocyanate residues in which both —NCO groups have been reacted; and the numbers indicate approximate molecular weights between these residues.

Atmospheric moisture will combine with the available isocyanate groups to produce a tightly cross-linked three-dimensional network throughout the film.

The average molecular weight per cross-link, calculated from the above idealized structure, is about 600. By suitable choice of the polyhydroxy components of the coating formulation, the average molecular weight per cross-link may be varied over a wide range. For example, the reaction product of:

	Moles
Polypropylene glycol (M.W. 1000)	1
Trimethylolpropane	1
HYLENE TM	4

will give a polymer with the idealized structure



Curing by exposure to atmospheric moisture will give a cross-linked polymer with a molecular weight per cross-link of about 1100.

A linear relationship exists between molecular weight per cross-link and extensibility of the cured film. Extensibility is directly proportional to cross-link density. A range from hard brittle resinous products to soft rubbery elastomers can be obtained.

The effect of molecular weight per cross-link on film properties is further illustrated in *Table* 8.

The data in *Table* 8 were obtained by curing the films at room temperature and 50% relative humidity. Similar results are obtained at relative humidities between 30% and 80%. The rate of cure decreases at relative humidities less than 30%, while exposure to more than 80% R.H. increases cure rate and film hardness.

Application

Either of the two types of coatings may be applied by conventional means, such as spraying, brushing or roller coating.

A urethane patent finish is applied in two coats. A linseed oil daub coat may be used, but better adhesion and solvent resistance is obtained if the daub coat is based on a hydroxylated linseed oil or Neoprene Latex Type 400. The urethane top coat is applied when the daub coat is dry.

Summary

The ADIPRENE L liquid urethane polymers may be cast as solid elastomers or sponges having outstanding abrasion resistance and excellent flex resistance and oil resistance—a combination of properties that make them of great interest in shoe construction.

Solutions of urethane polymers may be applied to give a patent finish to leather having excellent resistance to scuffing and cracking.

® Registered trademark for Du Pont organic isocyanates.

This article describes a method for improving over-all high speed performance of resin adhesive systems, by providing a means of isolating the cause of bond failure under dynamic loading conditions.

Effects of Rate of Loading on Shear Stress of Resin Adhesives

Raymond Braune, *Raytheon Company, Maynard Laboratory*
and
Melvin Silberberg, Ross H. Supnik, *Plas-Tech Equipment Corporation*

Considerable attention has been given to the effect of loading rate on the tensile lap shear strength of metal to metal bonds over the past few years.

ASTM Committee D-14 on Adhesives has only recently completed a round robin in Subcommittee I, concluding that loading rate has no effect on shear strength (1). This study however, was conducted over a very narrow range of loading rates in the static loading range.

Falk (2) developed a drop-impact test for measuring shear strength, and DeLollis (3) investigated a pendulum type shear impact test which ranked adhesives in a much different order than was done by tensile lap shear tests. However, as de Bryne and Houwink (4) pointed out, these techniques measure the energy absorbed by the test machine and by the adherends as well as the energy absorbed by the adhesives.

Schwartz and Wittman (5) reported on lap shear tests, for various adhesive formulations, made entirely in tension over a range of loading rates covering both the static and the dynamic loading range. Their results indicate that relatively hard rigid adhesives exhibit no change in shear strength as a function of loading rate, while soft flexible types have an increase in strength with increased loading rate. All of their data were obtained at room temperature.

This article examines the elevated temperature vs. the room temperature behavior of a number of representative adhesive systems in tensile lap shear over a wide range of testing speeds.

Materials

The following adhesives were evaluated in this study:

1. BR-89 (non rubber-based modified epoxy, Bloomingdale Rubber Company)
2. Metlbond 4021 (nitrile rubber modified phenolic, Narmco Industries, Inc.)
3. Metlbond 4041 (nitrile rubber modified phenolic, Narmco Industries, Inc.)
4. Epon 422 (glass-cloth reinforced epoxy, Shell Chemical Corporation)
5. RPR-A-210 (filled epoxy, Raytheon Company)

Sample Preparation

All samples were prepared and bonded according to standard laboratory procedures and manufacturers' recommended curing cycle.* In the case of Shell Epon 422, Aerobond Primer P-301.5 was used; in all other instances bonding was to the bare aluminum. Epon tapes were applied in accordance with Paragraphs 2.4 and 2.5, Federal Test Standard 175, Method 1033. Adherends were 6061-T6 aluminum alloy, 0.064 inches thick, for all samples except Metlbond 4021 and 4041, where 2024 aluminum of the same thickness was used. Samples were prepared with ½-inch overlap and with nominal 0.500 — 0.625 inch width in all instances, instead of the conventional 1-inch width, so that loads would be well within the capacity of the test apparatus used.

All samples were conditioned at 73 ± 2°F and 50 ± 2% R.H. for seven days prior to testing.

Test Equipment

Slow-speed tests (0.05 and 2.0 inches per minute) were conducted on the Instron Tensile Tester Model TT-C,[1] while high speed tests (200-2000 inches per minute) were conducted on the Plastechon Table Model 581 High Speed Tester.[2]

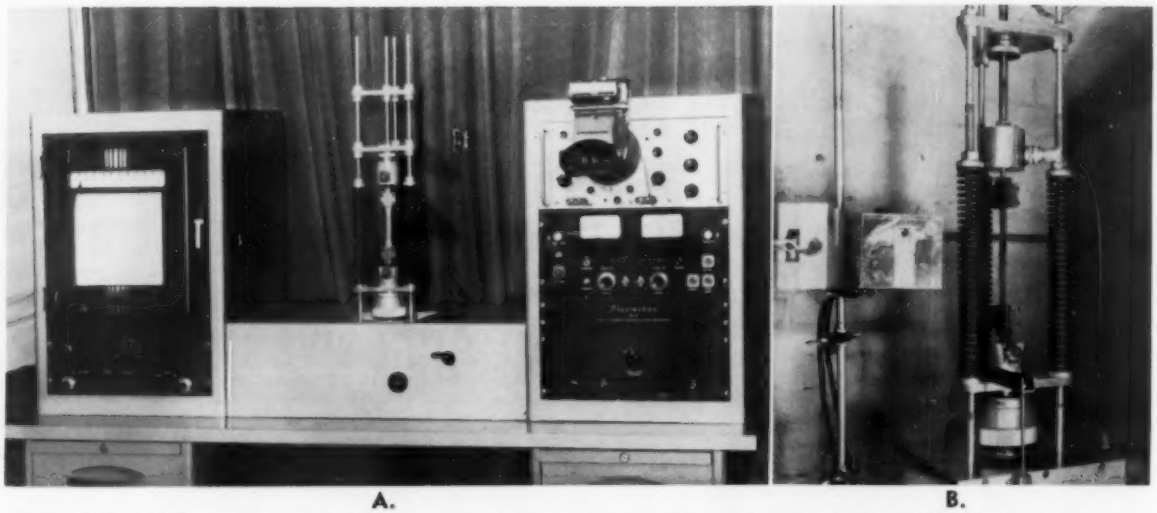
The Plastechon is a universal testing machine in which load is applied to the test specimen by the action of either a pneumatic or hydraulic cylinder. Rate of loading is controlled by the operating pressure and the amount of throttling in the exhaust line from the cylinder. Either load-time or load-elongation data are obtained as oscilloscope traces and

* A longer curing cycle might profitably have been employed in the case of the Bloomingdale material. The absence of same undoubtedly accounts for the reduction in performance for this material below the level reported by the manufacturer, but does not invalidate the directional effects observed as a function of either test speed or temperature in this study.

[1] Manufactured by Instron Engineering Corporation, Canton, Massachusetts.

[2] Manufactured by Plas-Tech Equipment Corporation, Natick, Massachusetts.

This article adapted from a paper presented at the First National Technical Conference in Los Angeles, October 13 and 14, 1959.



A. B.

Figure 1 (A & B). Plastechon High-Speed testing machine made by Plas-Tech Corp. (A). B shows close-up with heating fixture.

are recorded by means of a Polaroid Land camera. A photograph of this apparatus is shown in *Figure 1A*.

Elevated temperature tests were conducted with the use of the heating element (*Figure 1B*) designed by Twiss and Clougherty (6). A thermocouple is mounted in the unit in contact with the specimen, and a continuous temperature record obtained with a Leeds and Northrup recorder.

Procedure

A testing program was outlined which initially made use of a statistical design in an effort to obtain data and establish trends with a maximum of efficiency. As the testing program progressed, additions to the original statistical block were made as needed.

Tensile shear strength was measured as a function of loading rate at 73° and 300°F. In addition, lap shear performance as a function of adhesive thickness was also examined for Shell 422 by using tapes of 10, 12, 15 and 20-mil thickness. In all instances specimens were soaked at temperature for fifteen minutes prior to application of load.

Results

The results of this study are summarized in *Table 1* and *Figures 3 through 5*.

Discussion

The materials submitted for study can be classified as either highly rate-sensitive (i.e. the Narmco and Shell materials) or slightly rate-sensitive (i.e. the Raytheon and Bloomingdale materials) in performance. For applications where only static-loading conditions are to be met, materials of either type can be used to advantage. For dynamic-loading applications, however, it would be of appreciable value to know the degree of rate-sensitivity available. This is true not only on comparison from material to material but in the case of specific materials, e.g. Shell 422, which can themselves vary performance-wise as a function of some parameter such as glue-line or tape thickness.

The effect of molecular structure on the time-dependent mechanical behavior of the adhesive systems in question is predictable to a certain extent, with those systems possessing an elastomeric component demonstrating the greatest degree of rate-sensitivity. The increasing rate-sensitivity observed for the thinner tape thicknesses of Epon 422 possibly reflects an interaction—which may be sensitive to lay-up conditions in sample preparation—between glass tape and epoxy binder.

The effect of temperature as a variable on the performance of specific adhesive systems is critical in terms of such parameters as polymer stability, shift in brittle point behavior, etc. To date many materials which exhibit a heat-induced drop in mechanical properties under static-loading conditions have automatically been eliminated from consideration for elevated temperature adhesive applications. For applications which are static-loading in nature, such practice is to be recommended. For dynamic loading applications, however, we have seen that rate sensitive materials can (a) suffer performance losses as a function of temperature or (b) be heat stable under static-loading conditions, (c) demonstrate marked rate-sensitivity at elevated temperature, or (d) experience embrittlement at these temperatures as a function of the higher test speeds. Therefore, an evaluation under the service conditions which are actually to be encountered should be employed as far as practical.

An adhesive joint is a complex system consisting of adherents, adhesive, interface regions, and possibly a primer. It is important in evaluating such a system to know not only what load-bearing characteristics the system can provide, but also where and why failure occurs. *Since marked differences were observed in fracture pattern for static vs. dynamic tests in this study, a potential means of improving the overall high-speed performance of adhesive joints by isolation of the cause of failure under dynamic loading conditions is provided.*

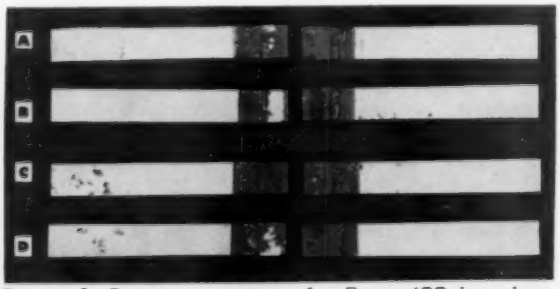


Figure 2. Fracture patterns for Epon 422 lap shear joints under static and dynamic tension loading conditions. A. 12-mil tape tested at 0.05 in./min. B. 12-mil tape tested at 3000 in./min. C. 20-mil tape tested at 0.05 in./mil. D. 20-mil tape tested at 3000 in./mil. For analysis see, page 555.

Table 1. Effect of Loading Rate and Temperature on Aluminum/Aluminum Lap Shear Strength for Five Adhesive Systems[1]

Loading Rate in./min.	Tensile Lap Shear Strength (PSI)															
	EPON 422								BLOOMINGDALE		METLBOND				RAYTHEON	
	10-MIL		12-MIL		15-MIL		20-MIL		BR-89		4021		4041		RPR-A-210	
	73°F	300°F	73°F	300°F	73°F	300°F	73°F	300°F	73°F	300°F	73°F	300°F	73°F	300°F	73°F	300°F
0.05	2510 (3)	1990	2830 (2)	—	1990 (2)	—	2230 (4)	—	2730	—	4010	1220	3150	970	2080	—
2.0	2350 (3)	—	3100 (1)	—	2170 (3)	—	2370	2420	2530	1740	4280	1220	3100	1110	2300	2320
200	2260	—	3510 (2)	—	2530 (3)	—	2500	2440	2700	1860	5930	—	—	1500 (2)	—	—
2000	4760 (3)	3530	3920 (4)	—	2960 (3)	—	2380	—	—	2550	—	3560	4300	2070 (2)	2380	1930 (2)

[1] All values are averages of five tests except as noted in parenthesis

An analysis of the data indicates the following:

(For graphical presentation of data, see Figures 3, 4 and 5)

1. The shear strength of BR-89 is insensitive to loading rate at room temperature, while some slight strengthening is observed as a function of increased testing speed at 300°F. In the static range shear strength at 300°F is 30% less than that at room temperature.

2. The Raytheon experimental adhesive RPR-A-210 exhibits some strengthening as testing speed increases at room temperature, but some embrittlement as testing speed increases at 300°F.

3. Metlbond 4021 and 4041 are both quite rate-sensitive, exhibiting appreciably higher values for shear strength at the higher testing speeds at both 73° and 300°F. Shear strength values at 300°F are only 30-50% of those at room temperature. It is interesting to note that the high-temperature dynamic-loading performance in the case of Metlbond 4021 is comparable to its room temperature performance under static-loading conditions. The 4041 material behaves similarly, but exhibits only two-thirds its room temperature static-loading value when tested under dynamic conditions at 300°F.

4. In the Shell 422 series shear strength increases as loading rate increases at both 73°F and 300°F for the lower thickness tapes, while the 20-mil tape is relatively insensitive to loading rate. The spread between the tapes is accentuated at the higher loading rates. Elevated temperature data are some 20% less than room temperature data in static tests, but some 10% more than room temperature tests at 2000 inches/minute.

5. For the thinner tapes at the higher speeds, the load-time curves show a definite yielding not observable in static tests.

6. For all the systems evaluated the type of fracture observed at the high speeds is substantially different from that observed in static tests. Thus, for example, the failure pattern for Shell 422 in the static-loading range is predominantly cohesive in nature, while under shock-loading conditions it is predominantly adhesive (Figure 2). The Raytheon and Bloomingdale adhesives show a similar shift to a more adhesive fracture pattern at the higher test speeds. The Narmco materials, on the other hand, show an opposite shift to more cohesive behavior at the higher test speeds.

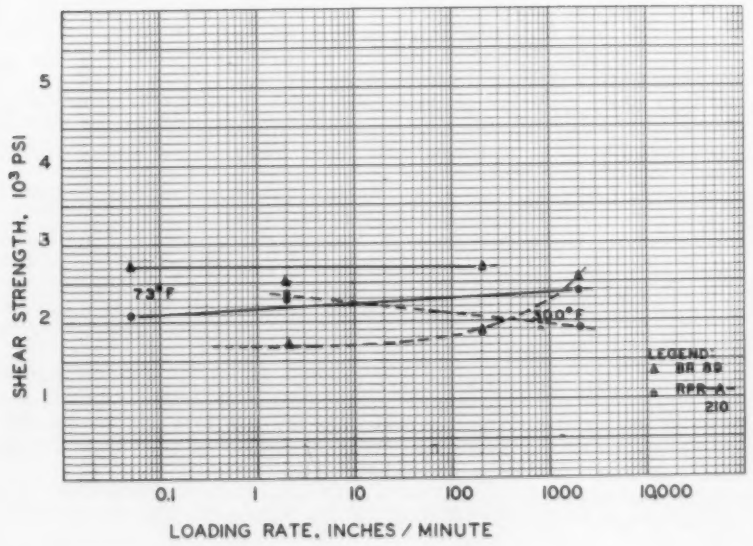


Figure 3. Tensile lap shear vs loading rate for BR89 & RPR-A-210.

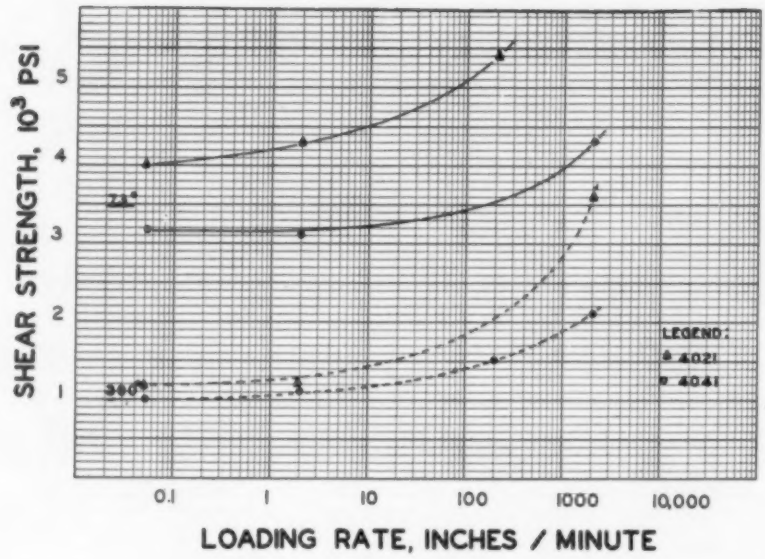


Figure 4.
Tensile lap shear vs loading rate for metlbond 4021 & 4041.

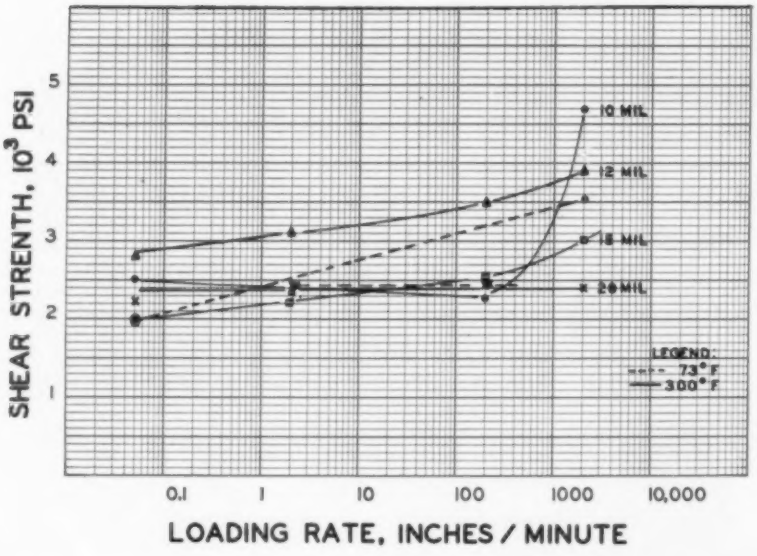


Figure 5.
Tensile lap shear vs loading rate for open adhesive 422.

The definite yield point observed in the dynamic test range for the thinner Epon tapes is quite unusual and reflects a certain visco-elastic behavior in the adhesive joint not observed in the static-loading range. This visco-elastic behavior under dynamic loading conditions should be of interest to the design engineer.

Summary

Tensile lap shear strengths of five (5) adhesive systems were determined at room temperature and 300°F over a broad range of loading rates. Two of the materials (BR-89 and RPR-A-210) exhibited little or no rate sensitivity and only slight temperature sensitivity. Two adhesives (Metlbond 4021 and 4041) were sensitive to changes in loading rates at both room temperature and elevated temperature. The fifth material (Epon Adhesive 422) exhibited increasing rate sensitivity with decreasing tape thickness. These materials are representative of the supported and unsupported tapes and putty-like adhesives commercially available at the present time for applications where elevated temperature service conditions are often encountered.

Acknowledgement

Thanks are due to the Raytheon Company, Waltham, Massachusetts and Narmco Industries, Inc., San Diego, California for preparation of test specimens and to George F. Murphy of the Plas-Tech Equipment Corporation for obtaining most of the experimental data.

Literature References

1. Unpublished data, ASTM Committee D-14 on Adhesives, Subcommittee I. American Society for Testing Materials, 1916 Race Street, Philadelphia, Pennsylvania.
2. Falk, A. H. "Impact Testing of Adhesives", *ASTM Bulletin, 141*, 42, (1946).
3. DeLollis et al, "Comparative Strength of Some Adhesive-Adherend Systems", *Transactions ASME*, 73, 183, (1951).
4. de Bruyne, N. A. and Houwink, R., "*Adhesion and Adhesives*", p. 482, Elsevier Publishing Company, New York, (1951).
5. Schwartz, R. T. and Wittman, R. E., "Effect of Rate of Loading on Shear Strength of Adhesive-Bonded Lap Joints", *Technical Report 54-153, Wright Air Development Center*, Wright-Patterson Air Force Base, Dayton, Ohio, December, 1954.
6. Twiss, S. B. and Clougherty, L. B., "Disk Shear Test for Adhesives", *ASTM Bulletin No. 232*, 57, September, 1958.

Physical Properties of Filled, Low-Density Epoxies

Kenneth D. Cressy,
Furane Plastics, Incorporated

This article describes epoxy foams with good insulating properties. Some applications include: Refrigerators, plastic boats, and other products requiring a combination of high strength and light weight.

A new series of low-density epoxies have been developed which have good physical properties for structural applications with the added advantage of a saving in weight. The low density fillers used in these epoxy formulations produce materials suitable for use in sandwich constructions, as casting resins, or as controlled-foam, light weight space filling material. There are several types of low density fillers now available for use in these light weight epoxy formulations; and each filler produces a type of syntactic foam with a unique range of physical properties. This article gives physical property data of several of these low-density epoxy formulations.

The fillers used in this study are tiny hollow spheres of expanded material, some being organic and others inorganic in nature. The uniformity of their shape enhances the strength properties of the syntactic foams made by combining these fillers with epoxy resin/hardener formulations. The uncured foams may be pourable for casting into irregular shapes for insulating or structural applications. They may be putty-like formulations which are ideal for troweling into honeycomb sandwich constructions, or they may be dry sand-like mixtures which can be tamped into place where light weight fill material is desired. The handling characteristics are determined by the amount and type of filler used, and this in turn determines the density and physical properties of the cured material.

Figure 1 shows the relationship of filler content to the density of the cured material. For this study, a common liquid epoxy/hardener mixture was used as a control to give a direct comparison of the several types of fillers. The particle size in each filler determines the amount of loading possible with Type A organic being the most effective in lowering the density. The upper limit of loading with Type A-2 filler appears to be about 70% with the density lowered to 0.43 g/cc. Type B-1 and Type B-2, both inorganic, permit greater loading but these fillers are less effec-

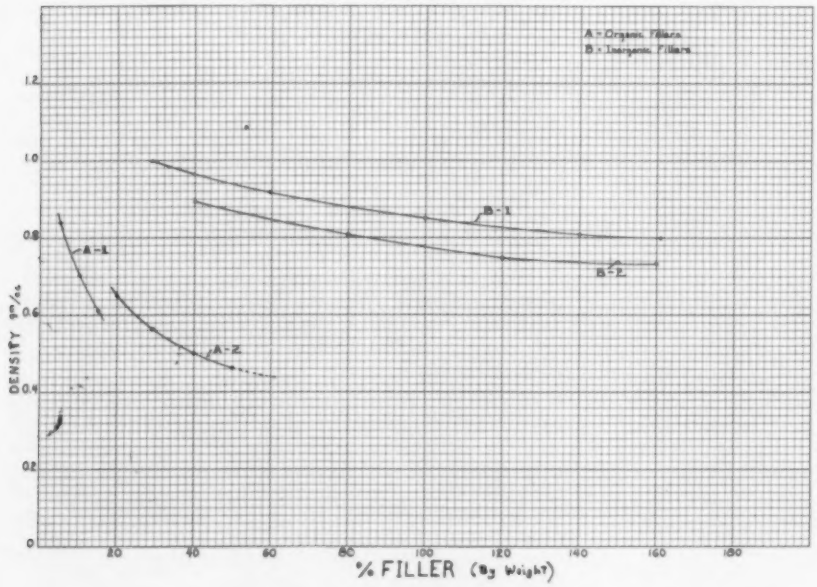


Figure 1. Density as Function of percent Filler.

This article adapted from a paper presented at the First National Technical Conference in Los Angeles, October 13 and 14, 1959

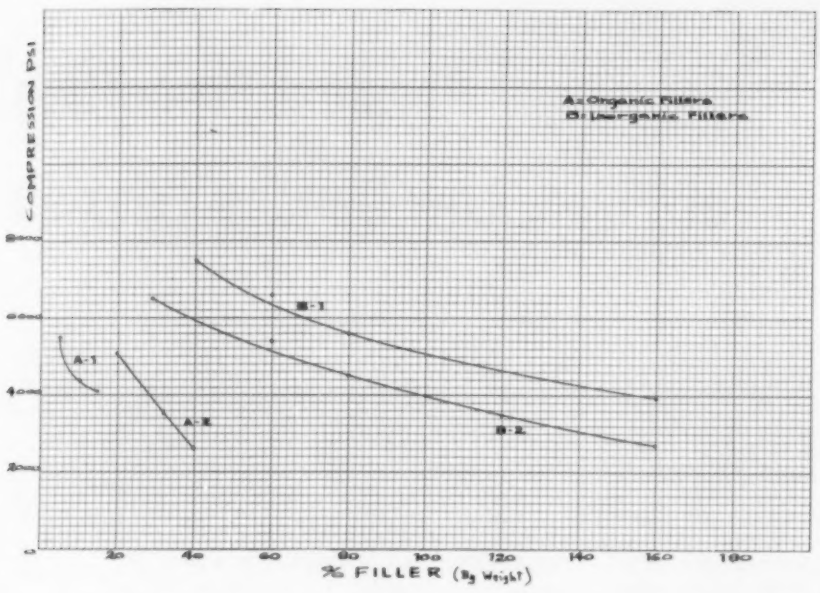


Figure 2. Compression as Function of percent Filler.

tive in lowering density. The maximum amount of loading was determined at the point where handling became impractical for ease of application. An interesting correlation appears in *Figure 2* as we observe the effect of filler content on the compressive strength of the cured material. The objective in the preparation of these low density epoxy formulations has been to reach the lowest density possible while maintaining the high degree of strength common to epoxies. By comparing *Figures 1 and 2*, we can determine the minimum point for each type of filler beyond which the compressive strength falls off rapidly while density remains at the minimum. Type A-1, having a very fine particle size, produced a thick unworkable paste and it became impractical to go beyond the points indicated.

A series of stress-strain curves in *Figure 3* show typical properties of both organic and inorganic fillers. The inorganic filler is more rigid and produces higher strength properties, while the organic type is more flexible and somewhat weaker in ultimate compressive strength.

A new type of inorganic microsphere is now available which, when blended in an epoxy formulation will produce an accurately controlled dielectric having a low density and resistance to high temperatures in the area of 500°F. Formulations have been prepared by combining the epoxy resin, curing agent, and low density filler into a one component, free-flowing powder resembling fine sand. This can be cured at temperatures above 250°F. to produce a rigid, feather weight foam with excellent dielectric properties and densities as low as 0.22 g/cc.

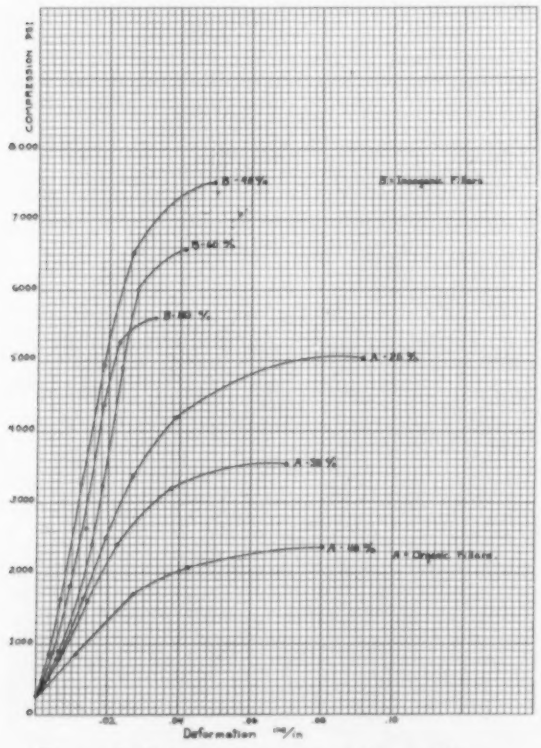


Figure 3. Deformation as Function of Filler.

Table 1. Physical Properties of Epocast 169

Average Density	— 35-40 pounds per cubic foot
Compressive Strength	— 6000 p.s.i.
Flexural Strength	— 2500 p.s.i.
Gel Time @ 80°F.	— 60 minutes
Service Temperature	— 250°F.

To illustrate a practical example of a light weight epoxy for structural uses, *Table 1* shows the properties of a typical formulation now being marketed called EPOCAST 169. Due to the excellent dielectric properties of the epoxy/hardener combinations, this filled, low density version may also serve as an electrical insulating or potting material. When used with a paste hardener, the compound becomes readily trowelable for use in honeycomb sandwich structures and other applications where non-flowing characteristics are desired. With the density of filled epoxy systems being on the average of 70-80 pounds per cubic foot, this new material at 35-40 pounds per cubic foot offers a considerable saving in weight.

The strength factors shown in the preceding figures may serve as guides in determining a specific application for one or more of these light weight epoxy formulations. The weight factor in aircraft and missile applications opens a wide area of use for these materials, keeping in mind also the excellent mechanical and electrical properties of epoxy resin systems. These syntactic epoxy foams have good insulating properties and can be used in refrigerators, plastic boats, and a variety of other end uses.

PLASTICS AROUND THE WORLD

This month's column has been made possible through the contributions of these abstracters:

Dr. Albert Lightbody (Australian Plastics & Rubber Journal)
Walter A. Gammel, Sr., (ASTM Bulletin and Rubber and Plastics Age)
Philip G. Fleming (Mechanical Engineering)
J. P. Harrington (Rubber Age)
John Shay (Electrical Manufacturing)
R. George Hochschild (Pensez Plastique)

Australia

AUSTRALIAN PLASTICS & RUBBER JOURNAL

DECEMBER 1959

Polyvinyl Acetate as an Aid in Plastering, pp. 18-19

A pre-coating of P.V.A. emulsion has been shown to give to wood, steel, tile and other smooth surfaces the adherence to plaster necessary for stability. Equal success has been had with butedienestyrene and acrylic ester emulsions. Test methods used and the performance obtained are given. Without the pre-coating, these smooth surfaces are almost impossible to plaster.

United States

ASTM BULLETIN

JANUARY 1960

Practical Method for Classifying Vulcanizates—pp. 69-73

An expanded tabular system of classifying and coding elastomeric vulcanizates that is simple yet universal is proposed. Developed by experienced practitioners, the chart provides guidance so the consumer cannot specify impossible or impractical combinations. Where no values exist in the table, it indicates no composition is available with that particular combination of properties or that no compositions having those properties has yet been needed by industry.

Accelerated Aging of Vinyl Plastic Compounds in a Modified Testing—pp. 43-51

Using a velocity of 400 fpm and 100°C., an oven design was developed that gave consistent results with different compounds, different oven, and different locations. The "tubular modification unit" adopted for these tests is pictured and described as is the method of determining flow rates.

FEBRUARY 1960

New-Tire Reinforcing Materials—pp. 76-81

An interesting article delineating technical development in plastic materials developed, or in the development stage, for increasing the dependability of tire carcasses, greater tire mileage and increased safety. Nylon 6/6, Dacron and polypropylene fibers are discussed.

The polyurethane materials are noted as very promising as monofilament materials of exceptionally good fatigue and tensile characteristics. All- polyurethane- fiber carcasses and polyurethane treads are currently being tested in Europe. The life expectancy is greater than 75,000 miles.

ASME TECHNICAL DIGEST

Brief Abstracts of Several Papers Presented at Recent ASME Meetings:

1. Plastic films in construction and agriculture (*59-A-261*) By: T. E. Werkema, The Dow Chemical Company, Midland, Michigan 1959 ASME Annual Meeting Paper (Multilithographed, available to October 1, 1960).
   This paper describes certain applications of polyethylene, in particular, and discusses physical properties of polyethylene, PVC, polypropylene, polyester and cellulose acetate films.
2. **Videne—A Polyester Laminating and Surfacing Film** (*59-A-361*) By: C. W. Taylor, Goodyear Tire and Rubber Company, Akron, Ohio. 1959 ASME Annual Meeting Paper (Multilithographed; available to October 1, 1960).
   Videne is described as a thermoplastic polyester laminating film; water-clear, unoriented, amorphous and non-crystallizing. By chemical definition this material is a linear copolyester. This material is said to offer Industry a new surface with unlimited possibilities of design flexibility and original effects.
3. **Polyethylene Pipe Progress** (*59-A-321*) By: A. Stockfleth, E. I. duPont de Nemours & Co., Inc., Wilmington, Delaware. 1959 ASME Annual Meeting Paper (Multilithographed; available to October 1, 1960).
   This paper covers the development, current status and the future status of polyethylene pipe.
4. **Uniform Two-Way Orientation of Plastic Films** (*59-A-113*). By: M. O. Longstreth, Member, ASME and Turner Alfrey, Jr., Dow Chemical Company, Midland, Michigan. 1959 ASME Annual Meeting Paper (in type-to be printed in Trans. ASME—J. ENGINEERING FOR INDUSTRY; Available to October 1, 1960).
   The flow-pattern involved in stretching a plastic film at equal rates in the longitudinal and tranverse direction is described in terms of diverging radial flow lines. The velocity of these flow-lines is said to be directly proportional to the distance from the convergences point.
   Design requirements for a machine to be used in the production of plastic film with uniform two-way orientation are presented.

NOTE: To order copies of the above papers from ASME—DO NOT order by title or context, Use Only the numbers that are underlined and in parenthesis, i.e.; (59-A-113).
Order direct from American Society of Mechanical Engineers.

RUBBER AGE

DECEMBER 1959

Carbon Black Loaded, Cross-Linked, Polyethylene in Wire and Cable—pp. 450-459

This article gives detailed information on the effect of varying concentrations of carbon black and a cross-linking agent (dicumyl peroxide) on the physical and electrical properties of low-density polyethylene. Comparative data are also presented for several competitive materials used for extrusion over wire and cable.

The advantages of curing polyethylene include an excellent stress-cracking resistance and a low degree of plastic flow at elevated temperatures. Suitable compounding with carbon black permits one to obtain combinations of properties which are desirable for some specific uses.

Fillers in Cross-Linked Polyethylene—pp. 837-840

This article compares the effects of varying concentrations of ground calcium carbonate and medium thermal carbon black on some physical and electrical properties of cross-linked, low-density polyethylene. In addition there is considerable data on the effects which the extent of cure has on several physical properties. The cross-linking agent used in these studies was 2, 5—bis (tertiary butyl peroxy)—2, 5—dimethyl hexane.

ELECTRICAL MANUFACTURING

FEBRUARY 1960

Improved Epoxy Resin System for Electronic Embedments

A "universal" type embedment compound has been developed by means of a liquid anhydride curing agent. The compound can be applied at temperatures up to 200°C as well as low temperatures. Manufacturing advantages are also indicated. Details of formulation and comparative test data are provided.

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PENSEZ PLASTIQUE NO. 173-175

DECEMBER 1959

A Rubber Based on an Ethylene-Propylene Copolymer—pp. 44

The ethylene-propylene copolymers, named C-23, are made by using special catalysts, similar to the ones discovered by Prof. G. Natta of the Milan Polytechnique Institute in the stereospecific polymerization of alpha-olefines. The production of these new elastomers represent another phase of the studies by Natta on directed polymerization, similar to the initial ones which resulted in "Moplen", the isotactic polypropylene.

According to the announcement by Montecatini, C-23 is a high molecular weight product made by the "pre-arranged" copolymerization of ethylene and propylene. Its properties are practically identical to those of natural rubber and surpass, in many instances, those of synthetic rubber. Its rebound at 20°C is close to 75 percent and its brittle point is well below that of natural rubber. Its excellent electrical and thermal qualities and its mechanical, chemical and physical properties are summarized in three tables.

Great Britain

RUBBER AND PLASTICS AGE

JANUARY 1960

Waxes in the Plastics Industry—pp. 59 and 60

Waxes are used in molding thermoset and thermoplastic resins to reduce tack and improve lubrication, hence improve release from molds.

Classifying and Blending Molding Powders—pp. 52-55

Air separators have an advantage over sifting machines where a high output and finer particle sizes are used for molding powders. In air separation, dust collectors are eliminated since it is desirable to use the same air repeatedly. In operation, the stream of dust laden air whirls down the outer casing effecting separation of the powder. Relatively clean air passes back to the inner casing through openings provided with deflectors which whirl the dust-laden air. Particle size can be controlled by varying speed of separator, by control of air volume, and by varying the number of blades.

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molded in Celanese Fortiflex
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NOW...THREE FLAME RESISTANT FORTIFLEX FORMULATIONS

New flame resistant Fortiflex is used as insulation in television yoke

In view of the increasing use of Fortiflex A linear polyethylene in electrical appliances where fire hazards can occur, Celanese now offers this material in three flame resistant formulations:

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- **FORTIFLEX A-250-12**
- **FORTIFLEX A-500-12**

These formulations provide a spread of melt indexes (0.7, 2.5 and 5.0 respectively), making it possible to mold a wide variety of flame resistant products. They are recommended for use in room air conditioners, refrigerators, electric motors, television sets, etc.

Flame resistant Fortiflex formulations are high density polyethylenes with a specific gravity of 1.04. They are available in opaque, white and black. Their stiffness, hardness and tensile strength are approximately the same as for standard Fortiflex A. However, heat distortion values under 66 psi are slightly lower and impact strength is somewhat reduced. Most important of all, the materials are self-extinguishing: burning rate or flammability is reduced to the point where they can be classified as non-burning materials under ASTM D-635-44.

Use Fortiflex flame resistant formulations wherever a self-extinguishing material is required.

More information is available. Write today for New Product Bulletin NP-35. Celanese Plastics Company, a Division of Celanese Corporation of America, Dept.129-E,744 Broad St., Newark 2, N. J. Celanese® Fortiflex®

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SECTION NEWS

Connecticut

Controlled Variable Speed Motors

K. G. Clarke

The March meeting of the Connecticut Section, Society of Plastics Engineers was held on Friday, March 11, at the Hotel Barnum in Bridgeport. Program Chairman, Ralph Esposito, of the W. S. Rockwell Company, Bridgeport, introduced the guest speaker of the evening, Mr. E. J. French, Field Engineer for U. S. Electrical Motors Company, Milford, Connecticut. His subject was "Controlled Variable Speed Motors."

Mr. French outlined the importance of choosing the correct type of motor for each plastic fabrication job. He cited numerous examples of how properly designed controlled speed equipment could provide processing advantages and cost savings to the user. A movie, describing several of these systems, was also shown.

Toledo

Alaska and the Alkan Highway

R. A. Davenport

An interesting and informative talk was enjoyed by the Toledo Section of the SPE at their February meeting. The topic: Alaska and the Alkan Highway. Speaker: Mr. William Pollock, former construction Engineer with the U. S. Army Engineers.

Upper Midwest Section

Plastic Decoration and Vacuum Metalizing

Charles M. Smith

"Vacuum Metalizing and Plastic Decoration" was the subject of a talk by Mr. Milton Z. Thorson of the Red Spot Paint and Varnish Company, Inc., for the February meeting. In addition to the lecture Mr. Thorson had on hand a very large display of hundreds of plastic parts decorated by the above process.

Mr. Thorson explained that vacuum metalizing or depositing of a thin aluminum film by high vacuum basically consists of the following:

1. a lacquer or enamel, referred to as the base coat is applied to the plastic part.
2. cure base coat place parts in vacuum chamber.
3. aluminum staples are evaporated.
4. and finally a top coat applied on metalized surface.

Equipment consists of a vacuum chamber, several different vacuum and diffusion pumps, racks and fixtures to hold parts and rotate them.

Pioneer Valley

Insulated Hot Runners

Roger Johnston

The large attendence on March 10, for the lecture by Virgil Smith of Phillips Chemical Co., showed the keen interest in hot runner systems.

Sprue designs gave many molders the original idea, but this development followed on from a hot runner system. Polyethylene and linear polyethylene with their low heat transfer are ideal in runners varying from ⅜"-1½" D. The thickness of frozen material varies little with cylinder temperature. The critical area is the gate, which has resulted in many variations; air gaps, internally heated sprue bushings and many shapes and sizes.

The volume of material flowing through the runner is critical and should be three times its volume. Cycles should be short, 2-12 sec. best with the maximum of 25 sec. It can best be used for balanced runners, though a heat balance can be attained for family dies. Linear polyethylene does not run well unless the sprue is pulled with the item. However regular polyethylene can use pin point gates.

This has proved a cheap easy way to overcome the runners of three plate molds, small daylight machines and degradation on regrinding runners.

Rochester

Rochester Hears Frawley

David L. Messenger

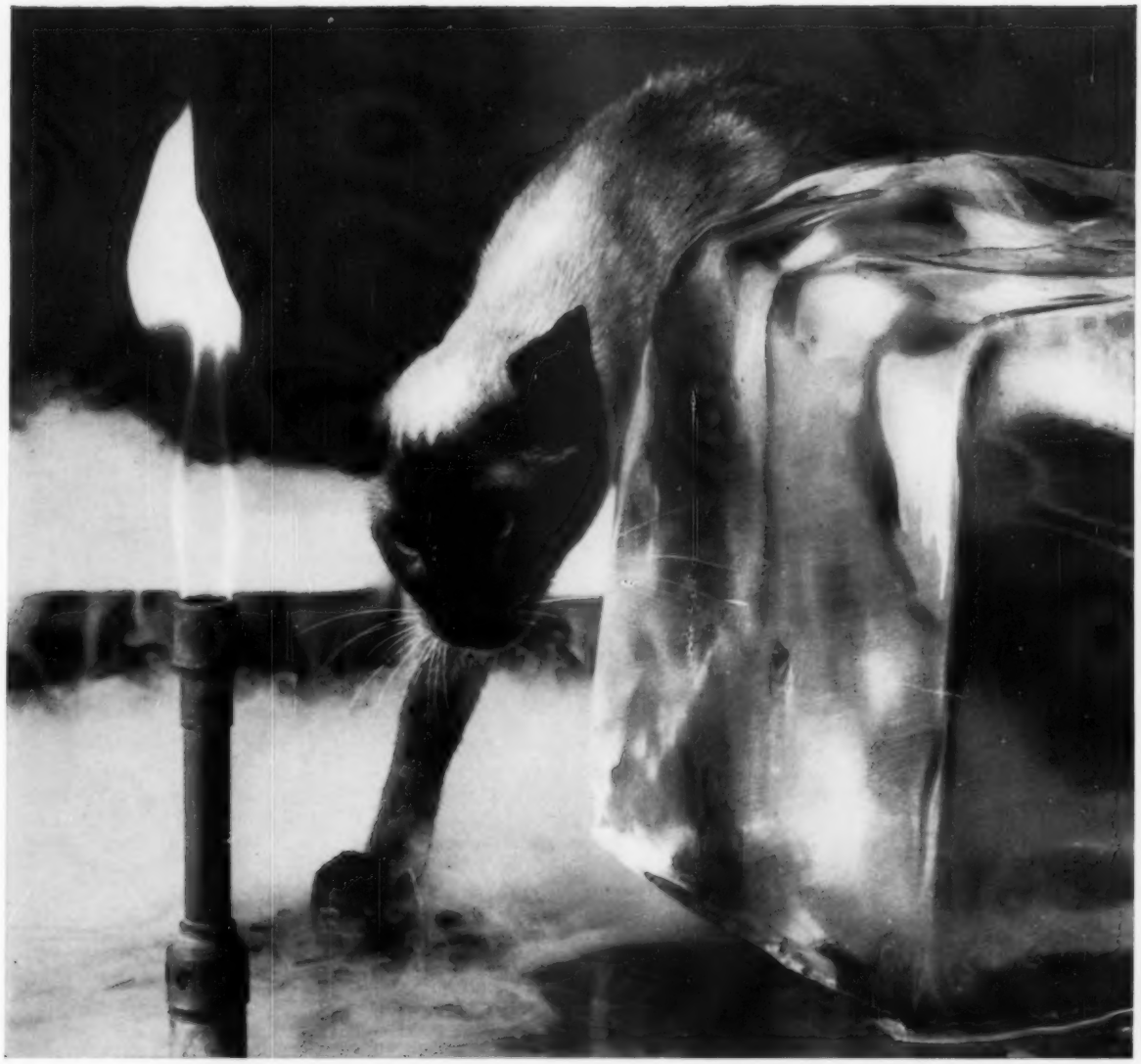
Mr. Robert J. Frawley of the Ferro Corporation was guest speaker at the March meeting of the Rochester Section. He spoke on the subject of Colorants for Plastics and explained some of the problems encountered both by compounders and molders.

Buffalo

Buffalo Sees Film

J. P. Valentine

The regular monthly dinner meeting was held on Monday, March 14, 1960 at the Park Lane in Buffalo. Special guests were Mr. George Martin, SPE President, and Mr. Jack Wilson, Dow Corning Corp. The meeting was opened by Mr. Arthur Engl, Vice President, with a report that William Dunmyer, President, has been in Niagara Memorial Hospital for five weeks and will be away from SPE for some time to come.



ARGUS TAMES THE ELEMENTS

Now your vinyls can do what you'd like them to do—and enjoy long life.

The proper Mark stabilizers and Drapex plasticizers condition your products to withstand most of the potential dangers to vinyls (heat, cold, sulphide gases, sunlight, etc.).

No matter what requirements your vinyls face—during processing or in final use—Argus can help you "build in" the needed stability, resistance, flexibility and hand to meet those needs successfully.

There is a wide range of Argus products to choose from—and when you have new problems to work out, *Argus gets the answers.* Our research chemists are ever on the alert to provide you with better and better stabilizers and plasticizers at less and less cost. Argus' high standards of quality assure a longer life-span for your products... more satisfied, repeat customers for you.

Don't hesitate. Call or write for consultation, technical bulletins, samples.

ARGUS CHEMICAL CORPORATION / New York and Cleveland

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For the technical part of the meeting, Mr. Wilson introduced a film entitled "Silastic RTV". The film described room temperature vulcanizing rubber. Applications include duplications of phonograph records, dental molding, and duplication of such things as foot and finger prints by law-enforcing agencies.

Milwaukee

Frank Reynolds Visits Milwaukee Section

C. H. Strong

The Milwaukee Section was honored in having Frank Reynolds, 1st Vice-President, National SPE for this meeting. Mr. Reynolds gave the section a brief talk on what the National Office Activities are in regards to the PAG's. His talk was inspiring and everyone present was very much interested.

Speakers were Dan Grzegorczyk and Ron Navratil of the A-C Spark Plug Company—Government Project Division. Mr. Grzegorczyk talked on the epoxy formulations while Mr. Navratil talked on testing of epoxies and testing equipment. Regarding epoxy formulations they talked about electrical applications in impregnating and potting. They discussed in detail filler, mixing of fillers, various modifiers, curing agents, and releases. In the testing of epoxies part of the talk, they discussed in detail the test and testing equipment. These were heat distortion, coefficient of expansion, specific gravity, shore and Rockwell hardness, along with various electrical tests.

Eastern New England Section

Four Technical Areas Discussed

D. V. Rosato

The March 22, 1960, meeting involved the presentation of the following four subjects:

Advances in Thermosetting Molding Equipment

A. L. Maiocco, F. J. Stokes Corporation, Phila., Penna.

A picture story was presented of new equipment developed primarily for automatic transfer molding. Semi-automatic transfer molding has been used for a number of years. However, automatic transfer molding without an operator has been a fact only for the past few months. Also, a brief coverage of the latest techniques in automatic compression molding will be given.

What Will Silicones Do Next?

K. R. Hoffman, Dow Corning Corporation, Midland, Michigan

The use of a wide variety of silicone products in electronics has expanded almost as fast as the electronics industry in the past decade. Silicones in the form of varnishes, coatings, laminates, fluids, lubricants, elastomers and molding compounds have all found applications. In addition to a short summary of the use of these various forms of silicones, the talk emphasized three new silicone products as illustrative of continued research and development in this area. The first of these products, the solventless silicone laminating resins, may be used to fabricate all types of electrical parts. They may also be used for encapsulating and wrapping, where protection of the enclosed part is a necessity. The second new product is Sylgard 51 Dielectric Gel. This potting material, which pours and flows easily into place, offers unique properties and advantages that solve a variety of electronic and electrical design problems. The third new system is called Sylgard 191 Encapsulant. It offers the opportunity of using a rigid silicone system to encapsulate certain precise electrical apparatus and offers thermal shock resistance and non-cracking along with the numerous desirable electrical characteristics inherent in the silicone materials.

The talk offered a description of the materials, their methods of application, properties, and examples of the adaptation to particular units.

Other technical areas discussed at the meeting were: *Aspects of Vinyl Floor Covering*, P. I. Johnson, Diamond Alkali Co., and *Some Practical Problems of Plastic Flooring* as it affects the consumer, by R. Wisotzky, Boston Woven Hose and Rubber Co.

North Texas

History of Polymer Development

Ernest F. Dourlet

The March 21 meeting of the North Texas Section, SPE, was held at Howard Johnson's Restaurant, with fifty-two members and guests present.

Mr. Clinton B. Howard, Monsanto Chemical Company, gave an informative talk entitled "Polymers, What?, Why?, How?" He pointed out that the term polymer was first introduced in 1833 and gave a brief history of polymer development from 1901 to 1940. Mr. Howard differentiated between condensation and addition polymerization and discussed methods of determining molecular weight. Also included in his talk were the reasons for developing certain polymers and the use of a property map to indicate the molecular weight desired.

Ontario

Automatic Injection Molding

Harold A. Shure

Details of the March meeting of the Ontario Section are as follows:

Date: Thursday, March 17th, 1960.
Place: Westminster Hotel, Toronto.
Attendance: 78 persons.
Subject: "Automatic Injection Moulding".
Speaker: Mr. Robert D. Schad. General Manager of Huskey Manufacturing and Tool Works (Ontario.)

Advantages of installing small capacity machines with fully automatic devices over larger units were described. A short comparison between U. S. and European methods of injection moulding was included.

Akron, Ohio

Linear Polyethylene

George Reesman

Mr. J. V. Smith of the Phillips Chemical Co. presented a very interesting talk entitled "A Discussion of Linear Polyethylene Injection Molding Advancements" before the Akron Section on Monday evening, March 28.

A number of colored slides showing mold design as well as insulated hot runner systems were shown. Mr. Smith had a number of complex parts molded of linear polyethylene to demonstrate that warp-free parts can be molded if proper mold design and molding conditions are met.

NOW RIGID VINYLS CAN BE MADE NON-TOXIC

Argus announces three new products—*non-toxic* stabilizers that *withstand the high heat needed to process unplasticized vinyl.* They provide stability superior to that of any non-toxic stabilizer previously available. All three are approved by the Food & Drug Administration.

The new, non-liquid stabilizers—Mark 33, Mark 34 and Mark 35—may be used in rigid compounds as the sole stabilizer system, and give excellent stability. They do not require the addition of epoxidized oils. Thus, they avoid the reduction in heat distortion temperature level and the loss of other important physical properties that occur with liquid-type stabilizers. They are suggested for use in extruded thin unplasticized film, rigid calendered sheet and plasticized non-toxic products.

Mark 33 gives exceptional long-term heat stability in rigids. It is recommended for pigmented or darker stocks. *Mark 34* is recommended where crisp, initial color is required, and provides good clarity. *Mark 35* gives better initial color than Mark 33, and longer stability than Mark 34.

Call or write for more information and bulletin.

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Mr. Smith stressed repeatedly the importance of proper mold cooling. "Impact strength decreases as mold temperature rises," he said, and demonstrated this fact by cracking linear salad bowls with a slight tap when they were molded hot as opposed to taking severe blows of a mallet with no ill effects when they were molded properly.

On May 20, a golf outing will be held at the Aurora Country Club. Cleveland Section members and guests are invited to this event.

Cleveland

Ford Plant Tour

E. K. McClellan

The annual plant trip of the SPE Cleveland Section was held this year on Monday, March 24, and consisted of a tour through the Ford Assembly Plant, Lorain, Ohio. This plant assembles Falcons and the new Comet.

After 63 members had been conducted on a very interesting tour the group met at the Saddle Inn at Avon Lake for dinner.

Philadelphia

Visualization of Extrusion

George R. DeHoff

On March 22 Chairman J. J. McGraw of National Vulcanized Fibre Company had two speakers on hand to give the Philadelphia Section an experimental analyses of the extrusion process as opposed to the more frequently discussed theoretical approach. Over 165 members and guests heard Mr. Glenn A. Pettit of the Wheelco Division of Barber-Coleman Co. discuss the latest improvements in pressure measuring devices, and Dr. Ernest Bernhardt of Du Pont describe the phenomenons revealed by a movie illustrating the flow patterns in screw channels and dies.

Mr. Pettit described the developments leading to the currently commercial strain gage that has proven not only very useful but also very durable for extrusion operations. This non-bonded strain gage, coupled with a suitable recorder can be used to monitor die or other pressures in the extruder. Since extrusion pressure is just as important as temperature, this monitoring system can be used to significantly improve the quality of production from a commercial unit.

Dr. Bernhardt introduced the movie on the flow pattern of viscous fluids in the channel of a screw which had been shown at the recent ANTEC in Chicago. Sections had been added showing flow of cubes in the feed section of the screw and flow patterns observed through a transparent die. Dr. Bernhardt used the movie to describe the flow factors influencing extruder output. He concluded his talk showing slides of improved melt thermocouples used in extruders and of high speed recording equipment used with these thermocouples and the pressure gages described by Mr. Pettit. He pointed out that this high speed equipment, being more expensive, is more commonly used in research and development work.

Central Ohio

Adhesives Subject of Talk

Richard B. Sharpe

Mr. Fred Wehmer, the Technical Director of General Adhesives and Chemical Company, Nashville, Tennessee, gave an interesting and educational talk on adhesives and how they can find application in the plastics industry. He emphasized that while the use of adhesives is a very old art, much is yet to be learned about the theory of how adhesion comes about. He also pointed out, through many examples, how important the proper design of parts and bonding areas and the selection of the proper adhesive are for a successful adhesive bond.

Southern California

Plastics in Rockets

Irwin M. Zelman

The March meeting was attended by approximately 150 people who came to hear a highly informative talk, by Ed Commeford of the Plastic Age Co., on "Plastics in Rockets and Missiles".

Mentioned were a variety of applications, from the nose cones to the motor sections. The resistance of various plastics to ablation was discussed and the best material so far to resist erosion and mechanical and thermal shock appears to be a nylon reinforced phenolic resin system. Examples were cited where recovered nose cones made from this system performed well although exposed to blasts of 12,000°F.

The uses of other reinforced plastics in missile bodies were then mentioned, where their excellent strength to weight advantages become important. Phenolics, phenyl-silanes, silicones, and epoxy resin systems each have an area of usefulness. The dielectric and radar transmission properties of plastics also show to good advantage for power units and guidance components. The freedom from handling damage and non-corrosion advantages were also pointed out.

Plastics are also becoming increasingly important in rocket motors. Some liquid engines have recently been tested that have fiberglass nozzles, but solid engines have, for some time, been using epoxy and phenolic filament wound motor cases and end grain and shingle fiberglass structures for nozzles. Much use is also made of plastics in the propellants.

It was emphasized that the suppliers must help the rocket and missile manufacturers in evaluating new materials to meet these specialized needs.

Present propellants are now beyond what can be controlled by plastic structures and further developments must be made to assure the advantages that plastics have to offer. Perhaps further combinations of ceramic materials with resin systems can be explored.

Mr. Commeford's talk concluded with a film of burn-out tests of solid propellant rocket motors.

Florida

Florida Hears Missile Expert

Jack Grosscup

Phil Betts of Bell Laboratories spoke to the Florida Section on "Reliability & Quality Control" at the Section's meeting, March 21st.

Mr. Betts is currently assigned to the Nike project at Cape Canaveral. With over 30 years experience with Bell telephone, Mr. Betts is an authority in this field. It was interesting to note that the basic rules and procedures for quality control in the fields of Electronics and Communications are essentially the same in Plastics.

The group was pleased to have Thomas A. Bissell, Executive Secretary of SPE as their guest. Mr. Bissell congratulated the Florida Section on their growth in little over a year of existence.

DRAPEX 7.7 BLOCKS STAINING—2 WAYS

Drapex 7.7, a primary plasticizer with polymeric properties, gives vinyls built-in resistance to stains. It *blocks stain penetration* from the top surface down and from the underside up. This explains its growing use in such vinyl products as floor tile and upholstery.

The low solvating rate of most polymeric plasticizers often causes processing difficulties. Because Drapex 7.7 has a very high rate of solvation, this problem is largely overcome. Similarly in plastisol or organosol coated fabric, through the use of Drapex 7.7 to increase fusion rate, polymeric properties may be obtained without the usual stringent heat conditions which often cause scorching of the fabric backing.

Drapex 7.7 gives vinyls low volatility and excellent resistance to extraction. Recommended for products coming in contact with chemicals—tank linings, vinyl coated gloves, etc.—and where resistance to lacquer marring is important.

Write for technical bulletin on Drapex 7.7 including results of stain tests.

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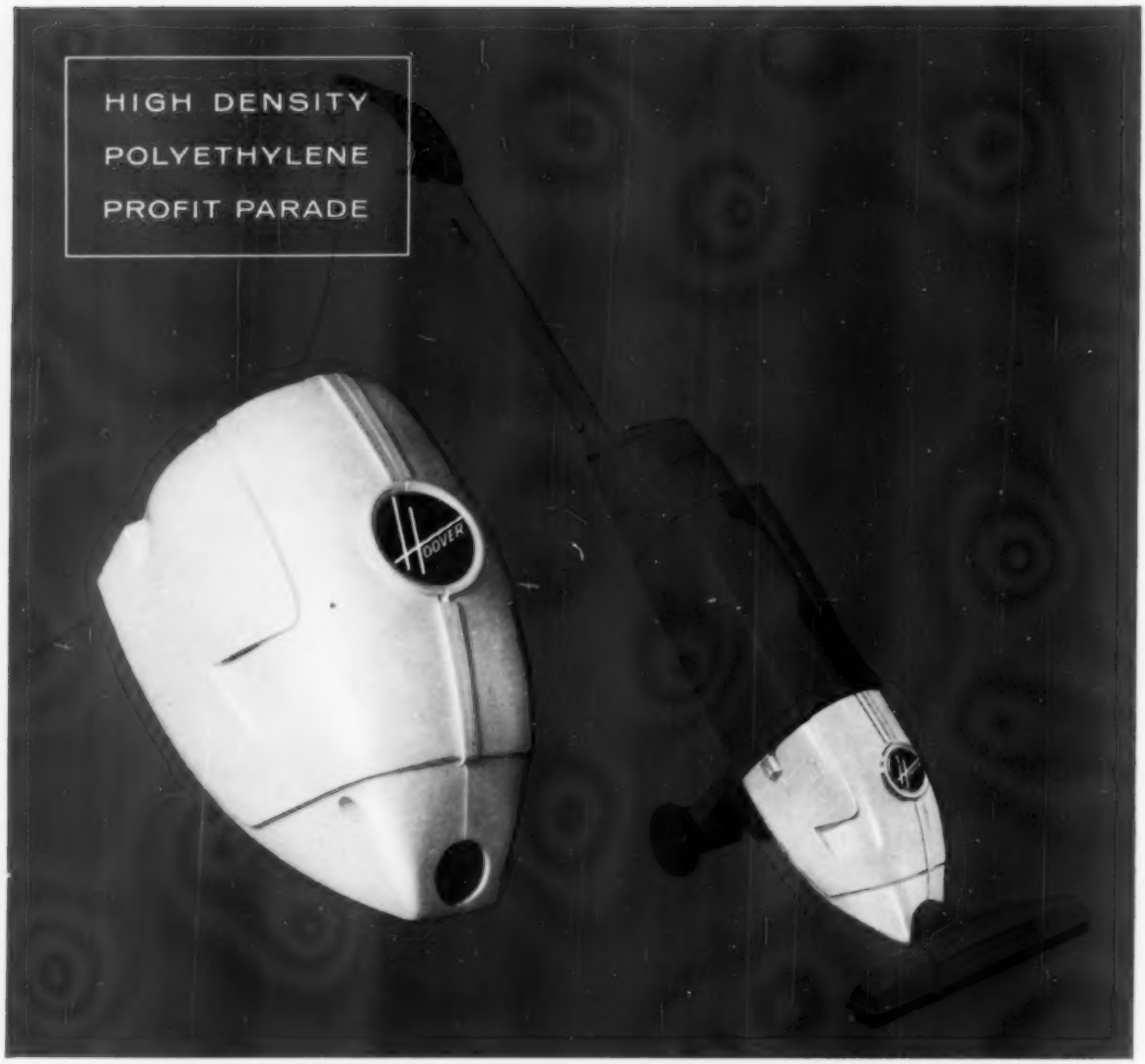


Grace Plastic Goes into New Appliance Concept

Are you working on a "new concept" product? High density polyethylene from Grace could provide a better answer to your product's unique requirements than any other raw material. The Hoover Company reached just such a conclusion in screening plastics for the motor housing of their new home appliance concept—an electric floor washer that cleans with its own detergent solution and dries by vacuum action.

Why did Hoover select Grex high density polyethylene? The motor housing has to be unaffected by moisture and the chemicals with which it comes in contact. It must withstand heat generated by the motor and possess high impact strength. Its color—a primrose yellow—has to be an exact match of the other parts. Just as important, the housing must be light in weight, economical to produce and flame retardant.

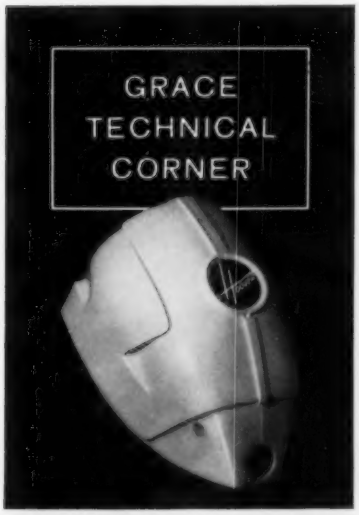
By specifying Grex, Hoover obtained the motor housing they needed. Although the requirements for your new product may not be the same as Hoover's, bear in mind that this Grace plastic offers many remarkable properties still waiting to be exploited.

Find out more about high density polyethylene by calling in the experts. Grace has the production facilities, technical service and experience to help put your product in the Grex profit parade. Everyone says we're easy to do business with.

Grex is the trademark for W. R. Grace & Co.'s Polyolefins.

W.R. GRACE & CO.
POLYMER CHEMICALS DIVISION

CLIFTON, NEW JERSEY



Hoover motor housing is one of many applications for Grex flame retardants.

Grex flame retardant at left is self-extinguishing.

Some of the most interesting problems encountered in molding the motor housing shown above are related to the use of Grex flame retardant compounds. If you have an application for this material, count on Grace for the same kind of technical assistance provided here.

Resin selection. Grace offers five different flame retardant grades. As a general rule, a grade with good flow characteristics is recommended for all but the smallest parts, bearing in mind that molding temperatures should not exceed 400° F. This project required use of the freest flowing since a relatively large shot is needed to fill the 2-cavity mold, and must flow in with minimum distortion.

Mold design. One of the objects in designing molds for high density polyethylene flame retardants is to obtain a short flow into the cavity with little change of direction. The motor housing mold was made to operate with greater efficiency by shortening its runner system and opening up its gates. Differential shrinkage and part distortion were avoided by redesigning the cavities to eliminate heavy sections and obtain maximum uniformity in wall thickness.

Call us first. We're ready and willing to provide technical assistance at any stage of your high density polyethylene projects—from conception to final production. It makes best sense to bring us into the picture as early as possible.

Technical Service Department
W. R. Grace & Co., Clifton, N.J.

Pittsburgh

SPE President Martin Visits Pittsburgh

C. A. Infante

The Pittsburgh Section of the Society of Plastics Engineers met on Thursday evening, March 17, 1960. This was "President's Night" and George W. Martin, SPE National President, was guest speaker. Mr. Martin discussed the National Organization of SPE, and emphasized that most of the groundwork in SPE is done at the local section level. He announced that Arizona would soon be with us with a new section possibly by May. There are also prospects of new sections in New Zealand and Australia. He stressed the importance of the professional activities of our organization and stated that they will be continually increased in the future for the betterment of SPE.

The main program of the evening was presented by Robert B. Way, President, and Howard P. Miskill, Design Engineer, of Finish Engineering Company, Inc. Their discussion, slides, and color films were on detail, decorating, and coating of molded plastics. Mr. Way pointed out that the three main reasons for coating plastic parts are: (1) to improve appearance (2) to give protection, and in some cases, (3) to hide defects. Many of the various methods of coating were described by Mr. Way and demonstrated in both his slides and the color film. Included among the various methods of coating were printing, screen process painting, hot stamping, vacuum metalizing, roller coating, fill and wipe painting, and spray painting. Mr. Way pointed out that the spray painting method was probably the most popular. Fill and white painting is very effective, although quite expensive. The most economical method of coating is roller coating.

Baltimore-Washington

Three Speakers at Washington

S. P. Prosen

The March meeting of the Baltimore-Washington Section held at the Rolling Inn in Baltimore was called to order by Taylor Birckhead, Vice-President of the Section. It was attended by 35 members and guests.

The speakers of the evening were Betty Lou Raskin of Johns-Hopkins University, Casimer Placewicz of Westinghouse Air Arm Division, and Felix Weinberg of Weinberg Prosthetics. Miss Raskin, in her talk gave interesting highlights on the London Plastics Exposition and Conference. The exposition was a world wide exhibit and especially noted was the lack of U. S. machines exhibited and the abundance of German machines exhibited. The conference was a 16-paper three-day affair. The papers contained only brand new material and the papers were not to appear elsewhere. Instead of preprints, post prints of the papers along with the questions and answers were published.

Mr. Plasewicz discussed the encapsulating of a magnetic coil using ceramic materials for a high temperature application. He discussed the problems encountered on curing such as thermal expansion differences causing cracking, and how these problems were overcome.

Mr. Weinberg showed a series of interesting slides on prosthetics. He discussed the steps in making prostheses and the materials used.

Newark

Newark PAC Active

B. M. Walker

Observation of flow in plastics extrusion is the subject of two lectures offered this Spring by the Extrusion Professional Activities Committee of the Society of Plastics Engineers, Newark Section.

"A Visual Study of the Flow of Molten Polyethylene in a Die" will be discussed Tuesday, May 17, at the Celanese Corporation auditorium in Summit, N. J., by Dr. E. B. Bagley of the Central Research Laboratory, Canadian Industries Ltd., McMastersville, Quebec. Dr. Bagley will present motion pictures of his work.

Bernard Zurkoff, chairman of Newark's Extrusion PAC, said in announcing the series that the events are open to all and are expected to be continued through this year.

introducing a new
injection molding machine...
with greater
moldability

the
REED-PRENTICE
12/16 oz. series

- faster molding speeds
- larger platens
- increased locking tonnage
- more plasticizing capacity
- longer stroke

all these features... and more... on
the new 350TC and 350TCL REEDS

Here are the facts on the new 12/16 oz. REED series, designed for greater molding profits through increased molding flexibility.

Exclusive monitor type safety circuit with all covers and guards in die area completely interlocked for maximum operator protection.

Push-button control on die plate located close to operator for quick accessibility.

Hydraulic mold setup and space adjustments avoid possible nozzle breakage in setting up molds.

Separate electrical panel with pyrometers and timers avoid machine vibration.

Plug-in type heater bands are used for accurate control of front, center and rear zones of heater.

Large, oversized cooler gives added advantage of running machine with 85° water.

One main electrical connection, completely wired—only one power source needed.

Plus: *oil immersed solenoids throughout • swing-out hopper • new indicator-type pump strainers • sight glass water feed control for molds • plug-in timers.*

	350TC	350TCL
Size of die plates	32½" x 32½"	32½" x 32½"
Mold clamping pressure (SPI strain gauge tested)	356 tons	372 tons
Diameter of tie bars	4"	4"
Space between tie bars	20½" x 20½"	20½" x 20¼"
Maximum daylight opening	36½"	44¼"
Mold clamping stroke (adjustable)	7½" to 14½"	8½" to 20¼"
Dry cycle time (Full stroke—clamp & plunger)	6¾ sec. (535 per hour)	7¾ sec. (465 per hour)

NOTE: 450 ton clamping mechanism available with 40" x 40" die plates, 26" x 26" between tie bars and mold clamping stroke from 6" to 22⅜".

See your REED Sales Engineer today for the complete facts about the new REED 350TC and 350TCL, 12/16 oz. machines.

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SOCIETY ACTION

Wanted: 8000 Salesmen

Who in the world wants 8000 salesmen?
As an SPE member you are qualified
to apply by reading the following application:

Sherman M. Crawford
SPE Membership Chairman

Once again your Society will have another International Section Membership Contest. This year the contest will run from April 1 to December 31, 1960, and will be governed by the same rules used in last year's contest.

Our goal this year is 9,000 or more members in good standing by January 31. By the end of this month we will have about 8000 members in good standing, including 99 student members. If every member would bring in one new member this year, it would more than make your Section membership chairman a happy fellow. It would go a long way in helping your Section to become our new Society grand champion for 1960!

The Society of Plastics Engineers was incorporated in 1942. The growth in membership can be attributed to an all-out effort by each and every member of the Society to bring in new members in the past to receive its growing benefits.

The greatest benefits the SPE has to offer a member are achieved through active participation on both the Section and International levels. Active membership in SPE is a powerful aid to the successful development of your career in plastics science and engineering. Your SPE Journal, your Section meetings, as well as "RETECs" and "ANTECs", all bring technical information of interest to members in both the engineering and scientific fields of plastics. The SPE Journal each month publishes for the first time outstanding engineering and scientific papers.

The Professional Activities Groups (PAGs) are at work providing a means for those interested in a particular technical phase of plastics to work together in solving problems and in raising plastics science and engineering to a more advanced level.

A member could very easily say, "so what? I know what the SPE can do and has done for me." This of course is true, but what about the fellow working next to you or the fellow you are calling on each day? Does he know the advantages of SPE? Does he know what the SPE Journal has to offer him in the way of plastics engineering and scientific information? Does he know that the SPE has 44 Sections throughout the United States and Canada to serve him?

I'll bet, if you took five minutes to discuss SPE with the fellow next to you, you could bring in a new member.

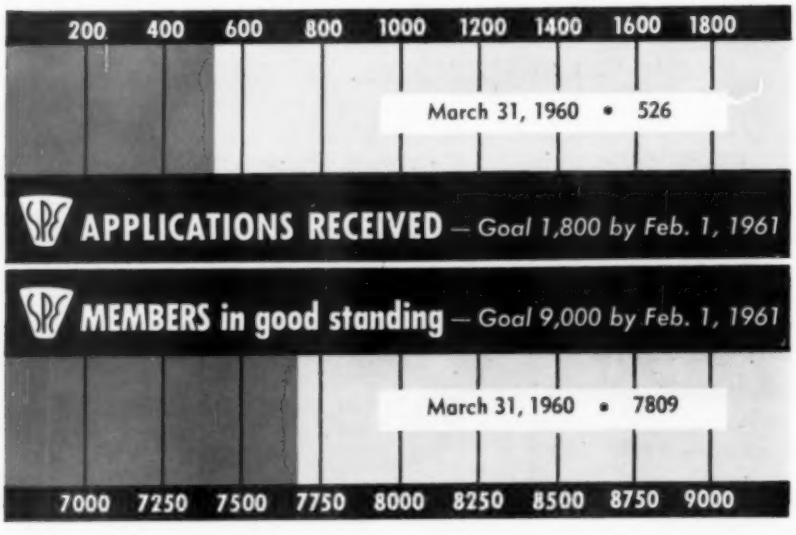
Contact your Section membership chairman today and ask him to send you the booklet, "What SPE Can Do For You", which includes an application blank.

Watch the membership barometer in your SPE Journal! As it grows you will be proud to know that each new member you bring in has helped SPE to reach our goal, and perhaps make your Section the Society's grand champion.

So, let's show President Martin and your local Section membership chairman that a goal of "9,000 plus" members in good standing, is too low an estimate for 1960.

It is hoped that as 1960 rolls along, more student Chapters can be added. The strength of any organization is in the development of its youth. This is a big program and it takes time to develop student Chapters.

As Henry Newman said, "The only way to make sure that you are not moving backward is to move forward".



edited by **Thomas A. Bissell**
SPE Executive Secretary

by Saul Gobstein

Chairman, Vinyl Professional Activity Group

PAG Progress

Steering Committee Sparks Vinyl Professional Activity Group

The Vinyl Professional Activity Group was officially started in the Fall of 1958. This group has organized a steering committee representing all segments of the vinyl industry while encompassing many sections. The following people, many of them authorities in their respective fields, make up the steering committee.

Name	*Section*	*Representing*
Saul Gobstein	New York	Chairman
Joseph P. Clancy	Philadelphia	1st Vice Chairman
Irvin Podell	New York	2nd Vice Chairman
Walter Waychoff	St. Louis	Secretary
Robert A. Abeles	New England	Past Chairman
Dr. Charles Chaban	Detroit	Calendering
John Olendorf	Detroit	Extrusion
Alva Whitney	New York	Coating
Don J. Spiro	Chicago	Laminating
Clair Milton	Balt.-Wash.	Finishing
D. A. Droudt	Cleveland	Molding
L. Whittington	Akron	Plastisol
Aberico Mascearelli	New England	Wire & Cable
Jack Parker	New England	Compounding
Richard Lee	New England	Records
Russell Park	Philadelphia	Suspension Resins
G. F. Cohan	Cleveland	Emulsion Resins
Herbert Rosenberg	New England	Stabilizers
Frank Felske	Philadelphia	Polymeric Plasticizer
Roy L. Kern	New York	Monomeric Plasticizer
Melvin Gerson	New York	Pigment

In the short span of our existence, the VIPAG has made some significant contributions to the Society.

1. The climate has been created for an interchange of vinyl information that has benefited the society, the industry, and the individual member. This atmosphere has made it possible for us to obtain papers of a higher caliber.

2. We are responsible for bringing into the Society several hundred new members. There is no doubt that a great many would never have joined if a VIPAG did not exist.

3. We have stimulated vinyl interest in various Sections.

4. We have assisted the Speakers' Committee of both the N. Y. and Chicago Annual Technical Conferences (ANTECs) in their Vinyl programs.

Today, in an age of specialization, it is only logical that the SPE turn to the PAG movement. In this way, the SPE can offer its membership:

1-the type of specialized programs he would want to hear at ANTECs, RETECs, and section meetings. (This can be made possible only by PAGs as these groups are best qualified to solicit, review, and select specialized papers.)

2-a base where technical committees can be formed to service the industry as well as answer any of its problems.

3-the technical stature that an SPE membership should stand for.

4-a greater opportunity for cross-fertilization and satisfying intellectual curiosity when contacting other specialized groups.

For a greater contribution from the Vinyl Professional Activity Group, or any other PAG, the membership, the Council and the Officers of the SPE must recognize the need and usefulness of the PAGs. The PAGs must be given a realm of responsibility to be able to prove this usefulness. Each PAG should actively participate with the ANTEC program committee in soliciting, reviewing and selecting papers for the Annual Conference. If this change in programming could be achieved this year, the officers and steering committee of the VIPAG would feel that the 1960 SPE administration had started us on the road towards making us *THE* Technical Society in Plastics.

—— ■ ——

edited by
Frank W. Reynolds, *PAG Administrator (International Business Machines Corp.)*

ABOUT MEMBERS

I. E. Becker is in charge of a new field research division of Extrudo-Film Corp. Mr. Becker will do research and development on polyethylene film for overwrap and automatic packaging machine applications, as well as new applications of polyethylene film.

Herbert G. Hard Jr. has been named Technical Staff Assistant, Orr Industries Co., Division of Ampex Corp. He is a graduate of Auburn University with a degree in chemistry.

K. W. Kithill was recently made Field Sales Manager with responsibility for supervising field sales force for Celanese Corporation of America.

R. M. Leiter has been appointed Sales Manager for molding compounds, Celanese Corporation of America. He is a graduate of Lehigh University (1944) with a B.S. degree in chemistry.

M. F. Antonovich now heads up Harchem's Purchasing Department. He formerly was Sales Manager for the Harchem Chemical Department.

R. D. Jackson is President of the new Honolulu, Hawaii Corp. Plastics Engineering of Hawaii, Inc. He and other key personnel were previously connected with the Liberty Engineering & Mfg. Co., Louisville, Kentucky. The Hawaii operation will be in the field of application of plastics for corrosion prevention. Mr. Jackson indicates that so far, response to the new venture in Hawaii has been excellent.

Marvin Levine has been appointed Director of Research and Development of the Plastics Division, General American Transportation Corp. He is a graduate of the University of Chicago and served with the U. S. Air Force during the war.

L. J. Hals appointed sales supervisor in the Detroit, Cleveland, Cincinnati, and Atlanta territories for Minnesota Mining and Manufacturing Co.

F. M. Ruggles, formerly Chemical Division salesman at Minnesota Mining and Manufacturing Company's Chicago area branch office in Bedford Park, Ill. has been named supervisor of sales for the Chicago and Dallas territories.

F. W. Troester will head sales for Minnesota Mining and Manufacturing Co. on the West Coast.

Jack A. Fletch has been named District Manager of the New York-New England area for Fiberfil, Inc. He succeeded Thomas P. Murphy who recently was advanced to the post of Development Manager for Fiberfil, Inc.

Eli Perry was appointed to a one year assignment with Monsanto Chemical Company's research laboratories in Zurich, Switzerland. He will do exploratory research work of his own selection.

THORESON-McCOSH, INC.

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HOPPER DRYER and new combination JET HOPPER LOADER

increases your production . . . soon pays for itself in savings to you!

Dries and preheats material at less cost than with conventional drying ovens.

Easy installation in a matter of minutes on any standard machine.

More production because of properly controlled conditioning of material.

Less material handling, with increased hopper capacity, no oven handling.

New Jet Loader maintains preheated condition of material. *No compressed air.*

For complete information write today. THORESON-McCOSH, Inc., 18208 W. McNichols, Detroit 19, Michigan, KEnwood 1-4700

Clifford R. Smith has joined the Dayton field staff of F. J. Stokes Corp. Mr. Smith was with Borden Chemical Co. for many years as Midwest sales representative. He is a past president of the Central Indiana Section of SPE.

Mr. Smith

Mr. Wurtzell

Frederick W. Wurtzell has been appointed Manager, Wire and Cable Market, for Union Carbide Plastics Co. He will be responsible for defining opportunities and objectives for Union Carbide Plastics in the wire and cable industry. Mr. Wurtzell has a B.S. degree in chemical engineering from the University of Illinois.

Werner T. Meyer was recently appointed general manager of foreign operations, The Kordite Co., Div. of National Distillers and Chemical Corp. He was director of Kordite's Engineering and Development Dept. Mr. Meyer is a graduate of the City College of New York, School of Chemical Engineering.

Mr. Meyer

Mr. Davidson

Robert L. Davidson was elected President of Kurz-Kasch, Inc., Dayton, Ohio, custom molder of thermosetting plastics. He has been with the company since 1946.

R. W. Sherman has been named Office Manager of the New England Regional Office, Union Carbide Plastics Co. In his new position, he will direct office functions of the Hartford regional office as well as in the Boston District Office.

Robert M. Stroman is now manager, Buffalo sales district, Hooker Chemical Corp., and **Edward F. Borro, Jr.**, is assistant product manager, molding compounds, North Tonawanda, N. Y. Mr. Stroman succeeds **Harry M. Dent, Jr.** who recently resigned and Mr. Burro succeeds **John F. Ortner**, now product manager, molding compounds.

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7

NEW BOOKS

Marine Design Manual for Fiberglass-Reinforced Plastics

By staff engineers, Gibbs & Cox, Inc., McGraw-Hill Book Co., 376 pages, $15.00.

How to gain high structural performance and maximum durability in designing or fabricating fiberglass boats is explained in this newly published book. It provides modern methods, principles, and data for using fiberglass reinforced plastics in marine or other types of large-area structures.

Boat hull design, molding methods, engineering properties of laminates, design of laminates—these and other major aspects are covered in the manual. Conservative design is stressed throughout.

A number of detailed design examples and illustrations of construction techniques take the reader step by step through the development of various boat structures. Included is a rowboat, a day sailor, a high-speed outboard, a 30-foot auxiliary sloop, and a 30-foot power cruiser.

Industrial Complex Analysis and Regional Development

By Walter Isard, E. W. Schooler, and T. Victorisz, Technology Press & John Wiley & Sons, 294 pages, $8.75.

"Given the existing state of social science knowledge, it is impossible to identify for all purposes a *best* set or *best* hierachy of sets of regions" for the analysis of the economic development of a certain area of the world.

(continued on page 577)

Employment & Service Guide

POSITIONS OPEN

DEVELOPMENT ENGINEER

NRM has an exceptional opportunity for a top quality project engineer. Substantial experience in blow molding or extruder design can lead to rapid advancement. Please send resume of education, experience and salary requirements to: E. E. Heston, Manager Extruder Division, National Rubber Machinery Company, 47 West Exchange Street, Akron 8, Ohio.

CHEMISTS AND CHEMICAL ENGINEERS

New Plastics Programs

The overwhelming success of our entry into the Epoxy Resin Field recently has created several openings for qualified Chemists and Chemical Engineers. Openings exist in Baltimore, Maryland, and Princeton, New Jersey.

APPLICATIONS CHEMISTS

B.S. in chemistry. 1 to 7 years experience in applied research or technical service in thermo-setting resins field, for applications research, sales liaison, technical service on new epoxies.

POLYMERIZATION CHEMISTS

B.S. to PhD., up to 5 years experience in Vinyl polymerization for new product development or process development.

PROCESS ENGINEER

B.S., ChE. with minimum of 5 years experience in polymerization process engineering. For pilot process development in new resins field.

Qualified applicants may send resume in confidence to: C. J. Cooley, Technical Recruitment Manager

FOOD MACHINERY & CHEMICAL CORP.
161 E. 42ND ST., NEW YORK 17, NEW YORK.

PLASTICS ENGINEER

Plastics Engineer, technical training and experience in injection and extrusion. Must be qualified in tool room. Box #4060, SPE JOURNAL, 65 Prospect Street, Stamford, Conn.

SUPERVISOR

Product and Process Engineering

Position open for Mechanical Engineer with main experience in Nylon injection molding and some experience in compression molding. To handle process development within the Plant and some travel and customer relations with regard to new product development. Responsible for supervision of design tooling and Quality Control. Age 30 to 45 years. Salary $12,000 to $15,000.

Box 3860, SPE JOURNAL, 65 Prospect St., Stamford, Conn.

POLYMER APPLICATION CHEMIST

B.S. or M.S. in the polymer plasticizer field. Strong interest in development of uses of polymers & plasticizers & related theory. Experience in plastics fabrication desirable. Send resume & salary requirements to:

Technical Personnel Supervisor
THE ATLANTIC REFINING CO.
3144 Passyunk Avenue
Philadelphia 45, Pa.

PLANT MANAGER

Plant Manager, Southern California to set up, equip and manage new plant for the manufacture of reinforced thermosetting molding compounds. Must have production experience and engineering background with knowledge of high pressure compression and transfer molding fields. Reply Box No. 3460, SPE JOURNAL, 65 Prospect St., Stamford, Conn.

MARKET DEVELOPMENT PLASTICS

Excellent opportunity in PennSalt Chemicals Corporation's new and expanding market development program in plastics. We are seeking a man with the following qualifications:

- Graduate Chemist or Engineer
- 3 to 8 years' experience in the fabrication and application of thermoplastics, preferably in the area of injection molding and extrusion
- Flair for market development and technical service work.

This position is in our Research Products Development Department, located at our Whitemarsh Research Laboratory in Suburban Philadelphia.

Please send resume of personal data, education, experience and salary requirement to:

Pennsalt Chemicals
ESTABLISHED 1850

PENNSALT CHEMICALS CORP.
RESEARCH PRODUCTS DEVELOPMENT DEPT.
P. O. BOX 4388, PHILA. 18, PA.

POSITIONS WANTED

CHEMICAL ENGINEER

Wanted—opportunity to be useful to a company with progressive ideas and a growing business. Graduate Chemical Engineer with a total of eight years experience including four years in rust preventives and four years in plastics. Work has been in development, technical service and liaison with supervisory experience in these areas. Familiar with materials and equipment used in manufacture and testing of rust preventive coatings, pipeline coatings and wrappers. Broad working knowledge of plastics, especially epoxies, polyesters and foams for use in coatings, castings, laminates and insulations. Prefer technical service and liaison work with aim toward administrative level after proof of ability. Location desired is West Coast.

Reply Box #4160, SPE JOURNAL, 65 Prospect St., Stamford, Conn.

MANUFACTURERS REPRESENTATIVE

Manufacturers Representative covering four states, desires additional line. Now representing custom cast foundry for cavity and core components. Strong on service, Tool Background. Box 3760, SPE JOURNAL, 65 Prospect St., Stamford, Conn.

CLASSIFIED RATES

"Position Open" and "Position Wanted"—Minimum charge: $7.00; per word. $0.25. SPE members in good standing are entitled to a total of three no-charge "Position Wanted" advertisements during any twelve month period, each ad not to exceed 50 words.

"Machinery, Equipment, Materials and Services"—Minimum charge: $15.-00; per word: $0.50.

All ads include one bold face caption line. Additional caption lines at $2.00 extra per line. Boxed ads (four side rules) $2.60 additional charge. Display ads of 1/6 page (5 inches depth) or more are charged at regular advertising space rates.

Last day for inserting ads is the first day of the month preceding date of publication.

EXPORT

Experienced in the export of plastic raw materials, particularly polystyrene, polyethylene and cellulose acetate as well as promotion and technical sales service. Graduated in Europe in Commerce, Finance, Administration and Export and received basic technical training in the field and laboratories in the United States and Canada. Knowledge of international trade, foreign markets, major languages and principal plastics with their processing.

Desire career opportunity in any suitable capacity with the foreign department of a reputable American concern preferably located in the N.Y. area.

Reply Box 3560, SPE JOURNAL, 65 Prospect St., Stamford, Connecticut.

ENGINEER

Extensive experience in thermoplastic compounding, testing, analysis, molding, applications, development and sales service.

Supervisory position required. Please outline nature of position and minimum salary. Eastern location preferred. Résumé sent on request. Box 3660, SPE JOURNAL, 65 Prospect St., Stamford, Conn.

PLASTICS ENGINEER

Age 31, B.S., Chemical Engineering, plus management and technical courses. Eight years diversified plastics experience including physical testing, reinforcement of plastics, and thermoset molding. Responsibilities include production control and development of thermoset materials. Desire position with plastic materials or equipment manufacturer. Prefer to locate in Delaware Valley area. Detailed resume available. Box 3960, SPE JOURNAL, 65 Prospect St., Stamford, Conn.

PLANT MANAGER

Complete knowledge of injection molding, sheet extrusion and vacuum forming. Excellent background with nine years of experience in all technical phases of engineering and production. Prefer location in southern New England or metropolitan New York area. Reply: Box 4260, SPE JOURNAL, 65 Prospect Street, Stamford, Conn.

NEW BOOKS

(continued from page 575)

Instead, this reference book chooses a definite but large number of combinations of variables in an analysis of the economic feasibility of locating an integrated operation of an oil refinery petrochemical and synthetic fiber combination activity and the influence of this activity on the environs specifically Puerto Rico.

In the analysis, the combinations of oil refinery operations, intermediate chemicals production, and various fiber manufacturers are considered in detail first individually and then in various numerous combinations. These detailed analyses consider many variations of operating conditions, sources of supplies and the problems of variations in revenues because surplus manufacture would be consumed outside the captive markets. Some of these analyses are considered in minute detail because the authors are competent to discuss them in the fields of economics, marketing and engineering.

Approximately three fourths of the book deals with the broad individual economic considerations for plant profitability and the effect on Puerto Rico complexes, while the remainder of the book comprises technical data in appendix form on a wide variety of materials. These technical data are in the form of programs of utilization for the various suggested procedures in the main text.

The book should be of interest to all who have to attempt to rationalize feasible programs from a maze of conflicting data pointing to many possible programs. As such it performs a very useful service.

The tables list new data in surprisingly large amounts to substantiate conclusions, or to list the results of the analyses. The reviewer persuaded an informed colleague to work up most of the above review, but it is evident to even the casual reader that this is a valuable reference for anyone who wishes to approach the problem of finding the best new industry for a specific locality. Appeals by chambers of commerce to industry should be more effective if they could afford to make similar analyses for their town or state.

Dr. Robert Bennett
Univ. of Fla.

TECHNICAL MEETINGS CALENDAR

17th ANTEC

Annual Technical Conference—January 24-27, 1961, Shoreham and Sheraton Park Hotels, Washington, D.C. Sponsored by the Baltimore-Washington Section. General Chairman: Dr. Gordon Kline, National Bureau of Standards, Washington, D. C.

1960 RETECS

Offers of papers in the technical area of each Regional Technical Conference are solicited by each sponsoring Section. Please submit offers and abstracts to RETEC Chairman or Section President indicated below for each RETEC:

September 8 and 9—New Horizons in Shoes and Vinyls, Eastern New England Section, Statler-Hilton Hotel, Boston, Mass. Co-Chairman, Program, Robert Abeles, c/o Elfskin Corp., Main St., Cherry Valley, Worcester, Mass.

September 22—Plastics in Business Machines, Binghamton Section, Sheraton Inn, Binghamton, N. Y. Chairman; John E. Gwyn, c/o Consolidated Plastics, 498 Conklin Ave., Binghamton, N. Y.

October 5—Plastics in Corrosion, Golden Gate Section. Chairman: J. W. Richardson, c/o Rohm & Haas Co., 600 California St., San Francisco 8, Calif.

October 19—Tooling for the Plastics Industry, New York Section, Hotel Commodore, New York City. RETEC Chairman—Arnold Meyer, 1877 Palmer Ave., Larchmont, N. Y.

November 7—Automation in Injection and Compression Molding, Ontario Section, Toronto, Ontario. Chairman: J. M. Lees, c/o Canadian General Electric Co., 755 Division St., North Cobourg, Ontario, Canada.

November 18—Blow Molding, Newark Section, Essex House, Newark, N. J. Chairman: Robert Hoehn, Mack Molding Co., Ryerson Ave., Wayne, N. J.

CONGRESS FOR MACROPLASTICS

The International Congress for Macroplastics will be held on October 17-19, 1960, Utrecht, Netherlands.

DETROIT RUBBER and PLASTIC GROUP MEETINGS

June 24—Summer Outing, Western Country Club.

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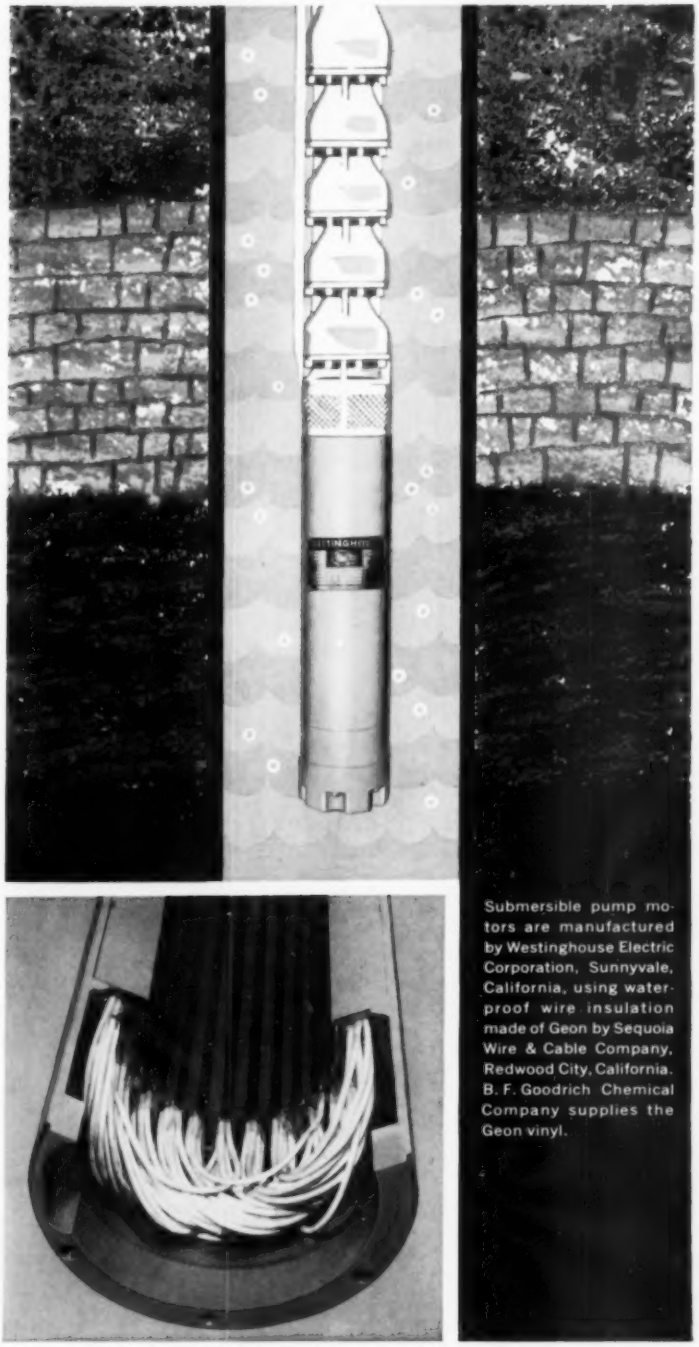

Submersible pump motors are manufactured by Westinghouse Electric Corporation, Sunnyvale, California, using waterproof wire insulation made of Geon by Sequoia Wire & Cable Company, Redwood City, California. B. F. Goodrich Chemical Company supplies the Geon vinyl.

Problem of motor submersion solved with Geon insulation

This new motor operates under water using the water itself as a lubricant. Since the housing is water filled and "breathes" well water, its operation depends on the insulation of Geon.

Geon met tough requirements. The manufacturer says that many materials were tested to find one that would stay waterproof indefinitely and also have enough mechanical strength to stand up under the winding process and under flexing imposed in starting.

A test motor was submerged under 400 feet of head for six months and subjected to frequent starting and operation. At the end of the test, the Geon insulation showed no signs of deterioration. Geon also eliminates need for thick and dense coatings over end turns—eliminating a cause of trapped heat and premature failure.

Here's another example of the way that Geon vinyls open new markets, or improve present applications. For more information, write Dept. GM-3, B.F.Goodrich Chemical Company, 3135 Euclid Avenue, Cleveland 15, Ohio. Cable address: Goodchemco. In Canada: Kitchener, Ontario.

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B.F.Goodrich Chemical Company
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